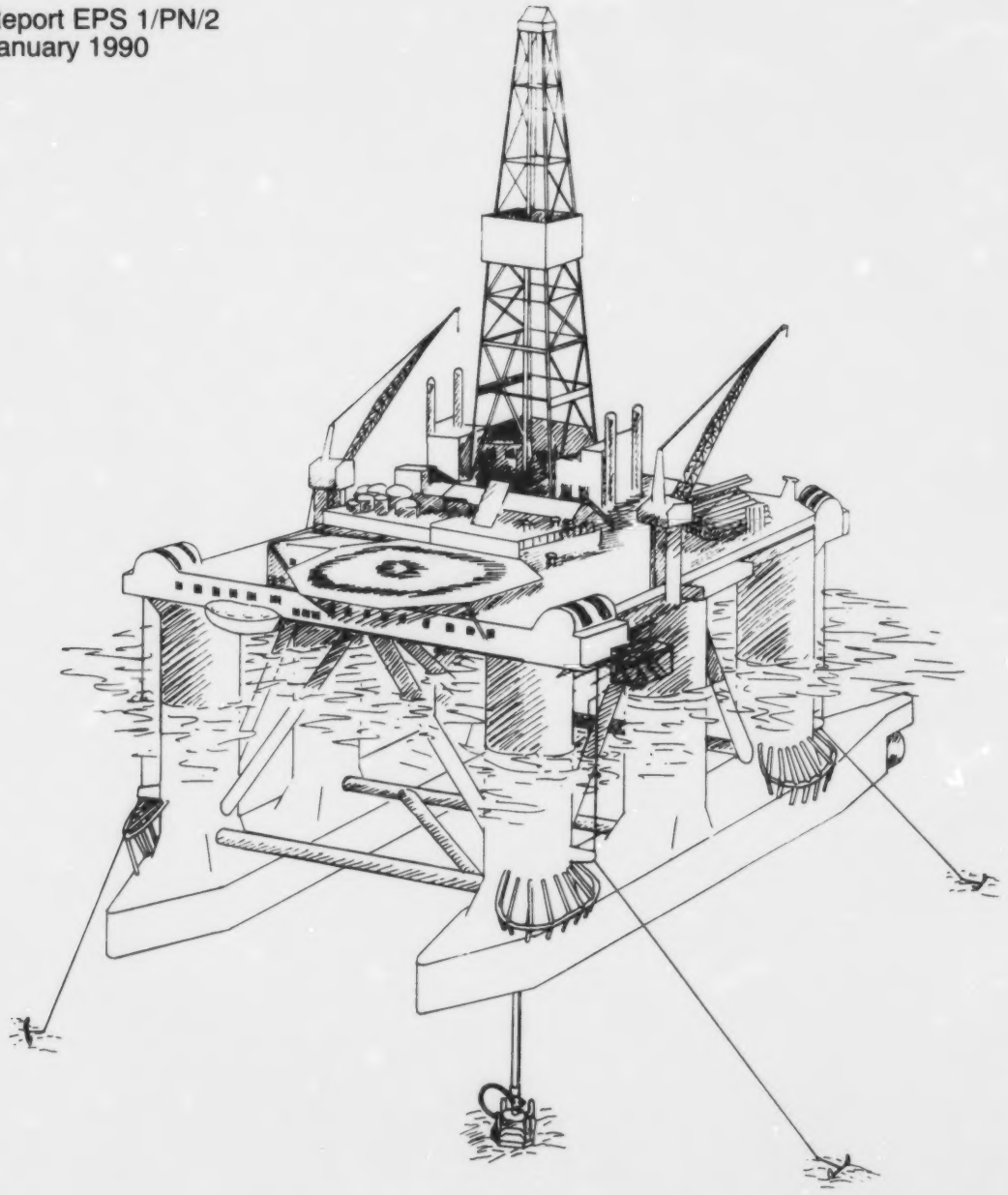
Environmental Code of Practice for Treatment and Disposal of Waste Discharges from Offshore Oil and Gas Operations

Report EPS 1/PN/2
January 1990



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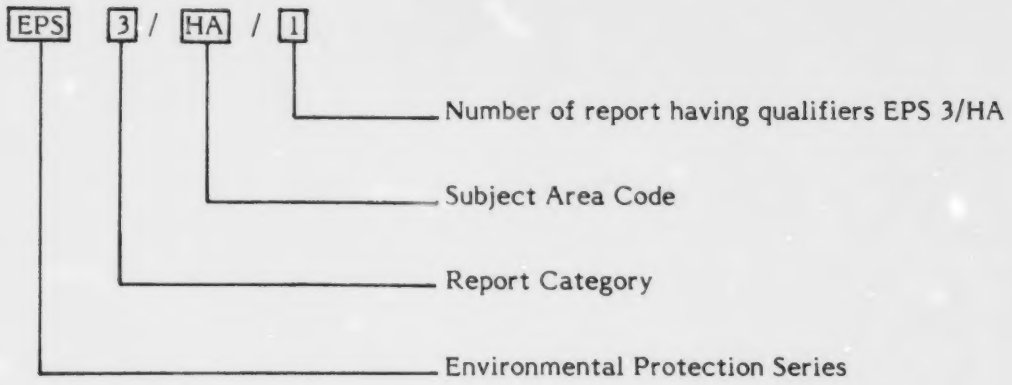

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ENVIRONMENTAL CODE OF PRACTICE FOR TREATMENT AND DISPOSAL OF WASTE DISCHARGES FROM OFFSHORE OIL AND GAS OPERATIONS

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READERS' COMMENTS

Readers who wish to comment on the content of this report may contact:

J.M. Osborne
Manager, Environmental
Quality and Assessment
Environmental Protection
Conservation and Protection
P.O. Box 5037
St. John's, Newfoundland
A1C 5V3
(709) 772-5488

or

K.R. Karr
A/Head, Oil & Gas Section
Industrial Programs Branch
Environment Canada
Ottawa, Ontario
K1A 0H3
(819) 953-1125

ABSTRACT

The "Code" presents Environment Canada's position on the level of waste treatment achievable at offshore oil and gas operations utilizing best practicable technology. It is designed to provide an information base for Environment Canada staff and others interested in waste treatment at offshore oil and gas facilities as well as a guide to the industry and regulatory agencies designing and approving waste treatment facilities.

The source, characteristics and treatment options available for each of fifteen potential waste streams are discussed. Recommendations are made on the discharge concentrations and volumes achievable with the application of best practicable technology. Potential design opportunities for new platforms are identified for specific waste streams. Incorporation of these design opportunities may reduce the discharge of oil and other products to the marine environment. The management and control of chemical usage at offshore sites is discussed with a view to establishment of a Chemical Notification Scheme for Canada. A modified version of the British Chemical Notification Scheme is appended for consideration.

The rationale for compliance monitoring is discussed and recommendations made to guide industry and government on the parameters to be sampled and frequency of sampling.

RÉSUMÉ

Le "Code" présente la position d'Environnement Canada sur le degré de traitement des déchets réalisable dans les installations pétrolières et gazières extracôtières à l'aide des meilleures techniques applicables. Il a été conçu pour servir de base d'information au personnel d'Environnement Canada et aux autres personnes qui s'intéressent au traitement des déchets dans ces installations, et pour guider l'industrie et les organismes de réglementation chargés de concevoir et d'approuver les systèmes de traitement des déchets.

Le Code traite de la source, des caractéristiques et des options de traitement de chacun des quinze flux de déchets possibles. Les recommandations ont trait aux concentrations et aux volumes de rejets que les meilleures techniques applicables permettent d'obtenir. Des possibilités d'aménagement des nouvelles plates-formes y sont présentées pour des flux de déchets donnés. L'intégration de ces aménagements pourrait contribuer à la réduction des rejets de produits pétroliers et autres en milieu marin. La gestion et la surveillance de l'utilisation des produits chimiques dans des sites extracôtiers sont analysées en vue de l'établissement d'un plan de notification des produits chimiques au Canada. Une version modifiée du plan britannique de notification est annexée à des fins de référence.

On y examine le bien-fondé de la surveillance du respect des normes, et les recommandations ayant trait aux paramètres à échantillonner et à la fréquence de l'échantillonnage se veulent un guide pour l'industrie et le gouvernement.

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1 INTRODUCTION

1.1 Scope

The Environmental Code of Practice for the Treatment and Disposal of Waste Discharges from Offshore Oil and Gas Operations, hereafter referred to as the "Code", identifies and recommends environmental protection practices for the offshore oil and gas industry. The document addresses all wastes potentially generated at offshore facilities including chemical additives utilized in drilling fluids and in treating wastes. Potential environmental concerns and alternative methodologies, technologies, practices and procedures designed to minimize adverse environmental effects from discharges are discussed. Recommendations are presented which are judged to be reasonable and practical for preserving the quality of Canada's marine environment with respect to discharges from oil and gas operations.

The Code is intended to be a source of technical advice and guidance to be used by the offshore oil industry, federal and provincial agencies and the public to identify opportunities to optimize environmental protection during exploration and production of offshore oil and gas in Canada. The Code is Environment Canada's position on the level of treatment achievable. The Code is being developed under the objectives, guidelines, and codes of practice provisions of Part I, Section 8, of the Canadian Environmental Protection Act (1988). While the Code is not regulation and does not have the force of law under Section 8, it helps to achieve the objective of the Act, namely the protection of Canada's natural environment. The Code is intended to be used with the guidelines developed by the Canadian Oil and Gas Lands Administration (COGLA). Compliance with the Code, however, does not remove obligations to meet federal, provincial, and other legal requirements. The more stringent discharge levels are viewed as goals that the industry should strive to achieve.

1.2 Code Development

The Code is based on the deliberations of the COGLA Waste Treatment Guidelines Advisory Committee and two background documents prepared for Environment Canada, "Offshore Oil and Gas Production Waste Characteristics, Treatment Methods, Biological Effects and Their Application to Canadian Regions (1983)", and "An Evaluation of the Performance and Cost of Waste Treatment Technologies for Offshore Oil and Gas Production (1985)". In addition, information from the United Kingdom, the Netherlands,

Norway and the United States on the utilization of "best practicable technology" (BPT) is incorporated.

Recommendations are based on the use of best practicable technology or best available technology (BAT) and where opportunities are foreseen to improve on discharge limits, state-of-the-art technology (SAT) is included. The recommended discharge limits may be more stringent than those in proposed guidelines but Environment Canada is confident that these levels can be achieved. It is recognized that other technologies and practices will be developed and utilized to achieve equivalent or better results in terms of environmental protection. Research directed at development and demonstration of improved environmental protection practices is therefore encouraged.

1.3 Code Structure

The Code has been prepared as an easy reference to recommended practices for the treatment and disposal of common waste streams from offshore exploration and production. Commencing with Section 2 and continuing to Section 14 each waste stream is discussed with recommended treatment and disposal practices, options and design opportunities (where applicable) identified.

The various chemicals used and their potential discharge routes are examined in Section 15. Abandonment and the planning required to reduce discharges at that time are discussed in Section 16 and a summary of recommended practices listed by waste stream along with a reference to where more complete discussion is provided in Section 17. Compliance monitoring of discharges including recommendations for the parameters to be sampled and frequency of sampling is discussed in Section 18. A potential chemical notification scheme to monitor chemical usage offshore is found in Appendix 1. Appendices 2 through 4 provide other information referred to in the guide and useful in its application.

2 PRODUCED WATER

2.1 Definition

Produced water is defined for the purpose of this Code as all water separated from crude oil or gas during the primary processing of oil and gas on offshore production platforms. It includes formation water and may include water injected to enhance oil recovery, where this water is recovered with produced oil.

2.2 Source and Characteristics

The volume of produced water from oil and gas production varies from field to field and with the age of the field (Table 1). The older the field, generally, the greater the volume of produced water. In cases where water injection is used to enhance oil recovery there is generally more water produced with the crude, especially where injection water migrates into the producing zone (break through). Estimates for produced water discharges from proposed production sites in Canada's offshore regions are based on limited exploratory information and extrapolation from world statistics. The estimates of maximum flow developed for the Hibernia and Beaufort Sea production scenarios are 14 000 m^3/day and 16 000 m^3/day respectively (Mobil Oil, 1985; Dome, et al., 1982).

Produced water contains insoluble oil, dissolved oil, other dissolved organics, dissolved salts and traces of heavy metals (Table 2). Produced water can also be contaminated with treatment chemicals, completion and workover fluids, biocides and oxygen scavangers from injection water. In other countries (Table 3) regulatory control has been directed at limiting the concentration of oil in the discharge of produced water. No significant effort has been expended to regulate other constituents of produced water although the Texas Railroad Commission is considering a limit on aromatic hydrocarbon content at offshore sites under its jurisdiction in the Gulf of Mexico (Barchard, pers. com., 1986).

2.3 Treatment Options

The treatment of produced water to reduce oil content can incorporate a series of steps. Most systems involve some variation on gravity separation (e.g., tilted or corrugated plate separators), which may be followed by induced or dissolved gas (air) flotation (Thomas et al., 1983). Present treatment systems considered as best practicable technology are capable of achieving 25 mg/L or less 50% of the time although chemical addition may be necessary to achieve this limit. Brown and Root (1984) reported the efficiencies of various oil water separation equipment used to treat produced water (Table 4).

TABLE 1 OFFSHORE PRODUCED WATER DISCHARGE RATES (Oil and Oil/Gas Production Platforms) (adapted from Thomas et al., 1983)

Location	Typical Produced Water Discharge Rates (m^3/d)	Produced Water Discharge Rate $\bar{X}$ (m^3/d)	Median (m^3/d)	Range (m^3/d)	References
Gulf of Mexico	8 to 16 000	-	-	656 to 1 600	Melligner et al. 1979 Goodman and Troake 1982 (1 platform)
		884	664	31 to 2 709	Jackson et al. 1981 (10 platforms)
		95	-	-	Middleditch et al. 1978
		1 877	552	56 to 24 000	Mors et al. 1982 (24 platforms)
	3 800 to 38 000	2 400	-	40 to 40 000	Maer 1975 (25 platforms)
		514	440	56 to 1 120	Myers et al. 1975 (4 platforms)
California		1 280	1 026	38 to 3 800	Shell 1981
		1 072	-	736 to 1 280	Myers et al. 1975 (3 platforms)
Cook Inlet		504	547	2 272 (max)	U.S. EPA 1982 (Granite Point)
		105	105	25 to 204	(Platform Bruce)*
		9 310	9 429	10 978 (max)	(Trading Bay)
		1 270	-	-	Lysyj 1982 (Kenai)
		1 750	-	-	(Dillon)
North Sea	24 000				Goodman and Troake 1982
		120	-	-	E & P Forum 1982a
		10 160	1 500	400 to 60 000	Schreiner 1980 (7 fields)**
		280***	-	-	Moore 1980 (Piper and Claymore Fields
		10 000****	-		Johnston (Piper and Claymore Fields), pers. comm.

Note: All values are per platform, except those for the North Sea which are for one or more fields.
* Produced water and deck drainage comingled.
** Maximum permitted discharge including produced water, deck drainage and storage displacement water.
*** At start-up.
**** Several years after start-up.

TABLE 2 MAJOR ORGANIC AND INORGANIC COMPONENTS OF PRODUCED WATER (adapted from Mobil Oil Can. Ltd., 1985)

Inorganic					Organic		
Ion	Hibernia (mg/L)	Avalon (mg/L)	Venture (mg/L)	Seawater (mg/L)	Component Parameter	Hibernia Prediction (mg/L)	U.S. Data (mg/L)
Na^+	67 732	27 500	30 000	10 760	Total Oil/(grav.)	35	2.3 to 359
K^+	1 016	991	276	387			
Ca^{+2}	7 085	2 536	20 816	413	Benzene	3.5	0.18 to 14.0
Mg^{+2}	669	575	31	1 294	Toluene	2.5	0.16 to 7.95
Ba^{+2}	NA	NA	NA	(3 to 50)	Xylene	0.5	
Sr^{+2}	NA	NA	NA	8	Ethylbenzenes	0.3	0.028 to 0.55
Fe^{+2}	trace	ND	trace	(0.9 to 1.61)	Naphthalenes	0.1	0.018 to 0.30
Cl^-	118 997	48 798	82 831	19 353	2,4-Di methylphenol		
Br^-	NA	NA	NA	67		0.1	0.016 to 0.57
NCO^{-3}	176	567	1 018	142	phenol	1.0	0.20 to 3.40
SO_4	71	260	853	2 712	TOC	300	68 to 661
CO_3^{-2}	0	0	0	NA	COD		182 to 3 000
OH^{-1}	0	0	0	NA	BOD		126 to 1 920
H_2S	ND	ND	ND				
TDS	195 746	81 227	NK				
pH	5.6	7.1	6.1				

NA - not analyzed; ND - not detected; NK - not known

TABLE 3 REGULATIONS ON DISCHARGE OF PRODUCED WATER (adapted from Thomas et al., 1983).

	Produced Water			
	Mean Oil Content Monthly Average (mg/L)	Mean Oil Content Daily Average (mg/L)	Trace Metals (mg/L)	Additives and Other Chemicals
Canada		40 (IR)*		
USA	48 (GR)	72 (GR)		
Region IX California		72 (GR)	As 0.032; Cd 0.012; Cr 0.008; Cu 0.02; Pb 0.032; Hg 0.00056; Ni 0.08; Ag 0.0018; Zn 0.08; Phenols 0.120; Cyanide 0.02	- halogenated phenols prohibited - surfactants, dispersants and detergents-discharge minimized except to comply with health and safety requirements
Region VI Gulf of Mexico		72 (GR)		- same as Region IX
Region X Cook Inlet	48 (GR)	72 (GR)		- produced water pH min. 6.0; max. 9.0 - deck drainage oil and grease average 65 mg/L, max. 90 mg/L
Norway	40 (IR)			- voluntary notification scheme
Great Britain	40 (IR)		- prohibited to discharge organohalogens; mercury and cadmium and their compounds; persistent oil and grease	- voluntary notification scheme which classifies products based on toxicity
Denmark	40			
France	20			
Australia (State of Victoria)		30 (max. 50)		

IR = Infrared Spectrophotometry; GR = Gravimetric Analysis

* Results are reported as total oil.

TABLE 4 SUMMARY OF VARIABILITY OF EFFLUENT OIL CONCENTRATIONS FOR DIFFERENT TREATMENT PROCESSES (adapted from Brown and Root, 1984)

	Effluent Oil Concentration Values not Exceeded Specified Percent of the Time (mg/L)			
Process Type	50%	90%	95%	98%
Flotation systems	25	50	70	100
Plate coalescers	35	100	130	200
Fibrous media coalescers	20	70	110	180
Loose media coalescers	15	40	50	60

Flotation units are designed to remove free or insoluble oil, and emulsified oil, when emulsion breaking chemicals are used. As well, they can contribute to a reduction of dissolved aromatic hydrocarbons by absorption in particulate oil and removal by rising gas bubbles. A one day study at the Kenai platform in Cook inlet indicated a 40% reduction in dissolved aromatics (Lysyj et al., 1981).

Although induced gas flotation is considered as best practicable technology for the treatment of produced water (E&P Forum, 1982a), alternate treatment methods are available (Figure 1).

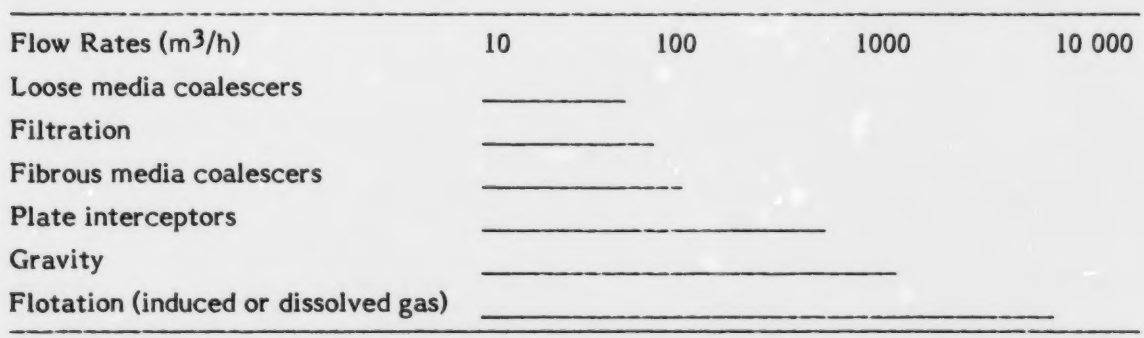

FIGURE 1 FLOW RATES FOR PRODUCED WATER TREATMENT SYSTEMS USED OFFSHORE (E&P Forum, 1982b)

An alternative to treatment is re-injection (not necessarily into the producing zone) of produced water. Re-injection eliminates the discharge of produced water and thus eliminates the concern for the discharge of other chemicals with produced water. Re-injection is utilized extensively on land and at some offshore locations. The U.S. EPA has announced its intent to require re-injection of produced water at all new production leases in sensitive areas (Federal Register, 1985). A problem with re-injection of produced water is the potential for plugging of reservoirs due to the precipitation of dissolved solids. Pre-treatment of the produced water is necessary to ensure the quality of the water is suitable for injection. The reservoir must also be suitable for re-injection.

In production fields where water is injected to enhance oil recovery, treatment technology exists that will prepare produced water for re-injection. The treatment required to make produced water suitable for re-injection is considerably more complex than that required to treat for discharge. Drilling separate disposal wells is not

considered as either practical or cost effective for the re-injection of produced water. (Milne and Green, 1985).

2.4 Recommended Practice

The following is recommended for the treatment and disposal of produced water at offshore oil and gas production facilities in Canada:

1. Produced water re-injection should be investigated at all production sites where water injection for pressure maintenance may be part of the development plan. In shallow water or near environmentally sensitive habitats produced water re-injection is considered to be the best option for protection of the environment.
2. For other offshore areas, if the produced water is not re-injected, treatment systems should be designed to achieve a total hydrocarbon concentration (30-day average) of 25 mg/L or less.
3. If the total hydrocarbon concentration, taken as the average value over a time period encompassing 30 days of activity, exceeds 40 mg/L, excluding treatment system upsets, a detailed report should be submitted to the regulator stating the reasons for the exceedence, including influent and effluent data, and the corrective action taken to achieve compliance.
4. Treated produced water, if discharged, should be released at a depth which will allow maximum dispersion.

2.5 Design Opportunities

In the design of new facilities for the production of oil and gas from offshore areas, opportunities may be available to incorporate systems which significantly improve effluent quality and reduce or eliminate discharges. The industry is encouraged to take advantage of these opportunities when they arise.

At least one such opportunity is available for produced water treatment by the use of gravity separation of produced water in oil storage cells in the platform. The crude oil is degassed and pumped directly to the storage cells rather than through a complex water separation system. The produced water separates from the oil during storage and the oil content is reported to be less than that achieved with standard treatment systems (Karr, 1986). Shell Oil U.K. is presently using this method in one of their North Sea fields. The platforms Shell operated in the North Sea were not designed for this purpose and they are experiencing some problems with hydrogen sulphide (H_2S) and scaling; although their produced water oil concentration continues to be less than 15 mg/L. The use of this system, therefore, would necessitate the design of increased storage capacity to allow for increases in the volume of produced water as the field matures as well as a mechanism to address the scaling and H_2S problems encountered by Shell U.K.

A new technology, the hydrocyclone, has recently come onto the market and is being used in the North Sea by Shell and Conoco. The hydrocyclone is modular and additional units can be added as the volume of produced water increases. These units are reported to be able to achieve 10 mg/L on a consistent basis. The advantages over conventional systems are reduced space and weight as well as ease of replacement.

3 STORAGE DISPLACEMENT WATER

3.1 Definition

Storage displacement water as defined for the purposes of this Code refers to water taken into and discharged from oil storage cells on an offshore production platform for the purpose of displacing crude oil during transfer to a tanker or pipeline and maintenance of ballast (Figure 2).

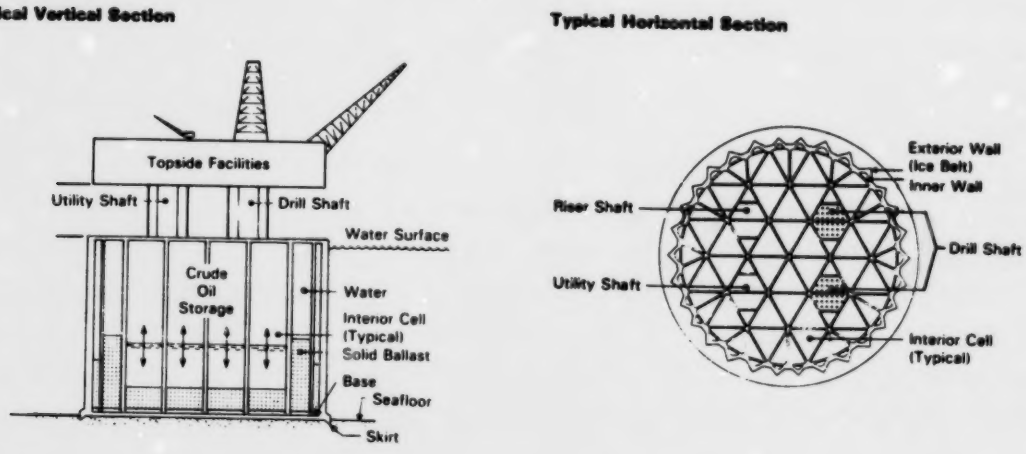

FIGURE 2 WATER AND OIL IN STORAGE CELLS (adapted from Mobil Oil Canada Ltd., 1985)

3.2 Sources and Characteristics

The volume of storage displacement water is directly proportional to the oil storage capacity of a platform. The average storage capacity of platforms operating in the North Sea is 150×10^3 m^3 (E&P Forum, 1982b). The storage capacity of the gravity base concrete structure (GBS) proposed for the Hibernia development will be approximately 230×10^3 m^3 (J. Ransom, pers. comm.).

Storage displacement water discharge rates will equal production rates of crude oil. Consequently discharges of storage displacement water will increase until the field is in full production and will decrease as the field is depleted. In the North Sea,

discharges of storage displacement water vary from 12 000 to 48 000 m^3/day (E&P Forum 1982b) and Mobil Oil (1985) has estimated 32 000 m^3/day for the Hibernia field.

The degree of oil contamination of storage displacement water depends on the solubility of the crude oil and its emulsifying characteristics; the length of time the crude is in contact with the water; and the turbulence created during the pumping of both crude and water. Most of the oil in the storage displacement water will be in the insoluble form (E&P Forum, 1982b) and easily treated. Average oil concentrations of the storage displacement water/ballast water prior to treatment are 300 mg/L (IOE, 1985). An emulsion of oil and water may be formed at the oil/water interface as a result of turbulence created during pumping. The emulsion is usually treated separately to recover the oil and the water effluent from this process is directed to the produced water treatment system.

3.3 Treatment Options

The treatment of storage displacement water is directed at the removal of insoluble oil. Corrugated plate interceptors and similar designs are the most commonly used technology for treating storage displacement water at offshore facilities in the North Sea (Milne and Greene, 1985). The various types of plate interceptors are essentially gravity separators with plates inserted to increase the coalescence rate of oil droplets. The plates increase the effective surface area available and reduce the effective oil rise height to enhance coalescence (E&P Forum, 1982b).

There are several types of plate interceptors. The three basic types are:

- parallel plate interceptors (PPI) which use horizontal or vertical plates spaced close together;
- tilted plate interceptors (TPI) which use parallel plates tilted at a 45° angle; and
- corrugated plate interceptors (CPI) which use corrugated plates to increase surface area.

Of these, the CPI units are considered the most efficient. Treatment of storage displacement water by the CPI unit has resulted in effluent hydrocarbon concentrations ranging from 2 to 50 mg/L, the average being about 25 mg/L (Johnston and Halliwell, 1976). Mobil Oil (1985) has estimated that storage displacement water from the Hibernia structure will be discharged at approximately 10 mg/L. As mentioned previously, retention time is the limiting factor in the removal of oil in most treatment systems and it is realised that storage displacement water may be best treated by long residence in the storage cells.

In some installations storage displacement water is directed to the produced water treatment system. This practice is not recommended due to the potential for creating treatment upsets from high intermittent flows.

3.4 Recommended Practice

The following is recommended for the treatment and disposal of storage displacement water at offshore oil and gas production facilities in Canada:

1. Treatment systems for storage displacement water should be designed to achieve a monthly mean effluent oil concentration of 25 mg/L or less total oil.
2. Discharge of the oil/water interface layer should be avoided. If the interface layer must be discharged, it should be pumped with the oil to the export tanker or pipeline.
3. Sludge from the periodic cleaning of storage cells should be recovered and shipped to shore for disposal or recycling or incinerated on site.

3.5 Design Opportunities

Designers should consider, in the design of new platforms, opportunities to reduce or eliminate effluent discharges. In the design of storage displacement water treatment the following should be considered:

1. Use of produced water for storage displacement water (see Section 2.5).
2. Where water flood operations are envisaged part or all of storage displacement water could be directed to the water injection system.
3. Influent ports in storage tanks should be designed to limit turbulence and thus reduce loss of product to the storage displacement water.

4 DRILLING FLUIDS AND CUTTINGS

4.1 Definition

Drilling fluids (muds) are defined for the purpose of this Code as a mixture of chemicals and inert materials in a carrier fluid, either oil or water, used to assist in the drilling of a well. Cuttings are defined as the particulate matter generated by the drill bit as it penetrates the formation.

4.2 Source and Characteristics

Drilling muds are generally classified by the carrier fluid, e.g., a water-based mud (WBM) where water is the liquid continuous phase, an oil-based mud (OBM) where oil forms the liquid continuous phase. The initial sections of the hole may be drilled with a spud mud consisting almost exclusively of bentonite and water. As the depth of the hole increases more specific application material is added. A weighting agent, either barite or hematite, comprises the bulk of the material added.

The volume of drilling fluid used is directly proportional to the volume of the hole and the volume of the mud room tanks. The estimated volume of mud required for a well at the Hibernia site is 6 to 7 x 10^3 m^3 per well water-based mud and 500 m^3 oil-based mud (Mobil Oil, 1985). The water-based mud will be discharged with cuttings while drilling and a possible bulk discharge of 500 m^3 may be dumped at the completion of the well. The oil-based mud is not discharged although some oil adheres to cuttings and is lost.

The volume of cuttings produced is directly proportional to the volume of the well. The volume of cuttings is usually greater with water-based mud than with oil-based mud because additional material is produced with water-based mud when sections of the hole cave in (washouts) due to the water sensitivity of the formations. The use of oil-based mud usually results in the drilling of a near gauge hole. It is estimated that a total of 1100 m^3 of cuttings will be discharged from the drilling of a production well at Hibernia; 900 m^3 from water-based mud and 200 m^3 from oil-based mud (Mobil Oil, 1985).

The discharge of drilling mud and cuttings occurs on a continuous basis during the drilling of a well. Bulk discharges occur when the formulation of the mud is changed to meet the drilling needs. Bulk discharges occur over short periods at high rates, (80 to 110 m^3/h) and at the completion of a well (Mors et al., 1982).

4.3 Treatment Options

The primary function of the treatment systems for drilling muds on exploratory and production platforms is to separate the cuttings from the mud. The process is a physical process involving a series of vibrating screens (shale shakers) to remove coarse cuttings, followed by a series of desanders and desilters (centrifuges) to remove finer cuttings (Figure 3). The separated cuttings from each stage are discharged overboard and the mud is recirculated. This basic system is used for the separation of cuttings for both oil- and water-based muds.

The treatment of cuttings beyond this stage for water-based mud is not considered necessary for protection of the environment. Additional treatment is usually necessary for cuttings generated during the use of oil-based mud to reduce the quantity of oil adhering to the cuttings discharged. The additional treatment can range from a simple water wash to sophisticated organic extraction systems designed to remove 99% of the oil. The majority of these cuttings wash systems use a solution to wash the cuttings that may be more toxic to marine species than the oil and the wash solution must be disposed of when it has been exhausted. Wash solutions have been used by operators in the North Sea in order to meet discharge limits on the quantity of oil on discharged cuttings. The UKOOA (1984) conducted a study which concluded that the mean oil concentration on cuttings discharged in the North Sea, without additional treatment other than standard solids control, was 15 g oil/100 g dry cuttings $\pm$ 5 g. Present guidelines in Canada (COGLA, 1985) require the operator to meet an average level of 20 g oil/100 g dry cuttings calculated over the period of drilling the well with oil-based mud (Appendix 4).

4.4 Recommended Practice

The following is recommended for the treatment and disposal of drilling fluids and cuttings at offshore exploration and production facilities in Canada:

1. Well maintained and operated standard solids control equipment, consisting of shale shakers, desanders and desilters, should be considered as best practicable technology for the separation of cuttings from mud for water-based mud.
2. If the bulk discharge of water-based mud is necessary at the completion of a well, it should be performed in a manner which ensures that the solids portion of the mud is deposited in the same area as the cuttings and that maximum dispersion of the liquid fraction is achieved.

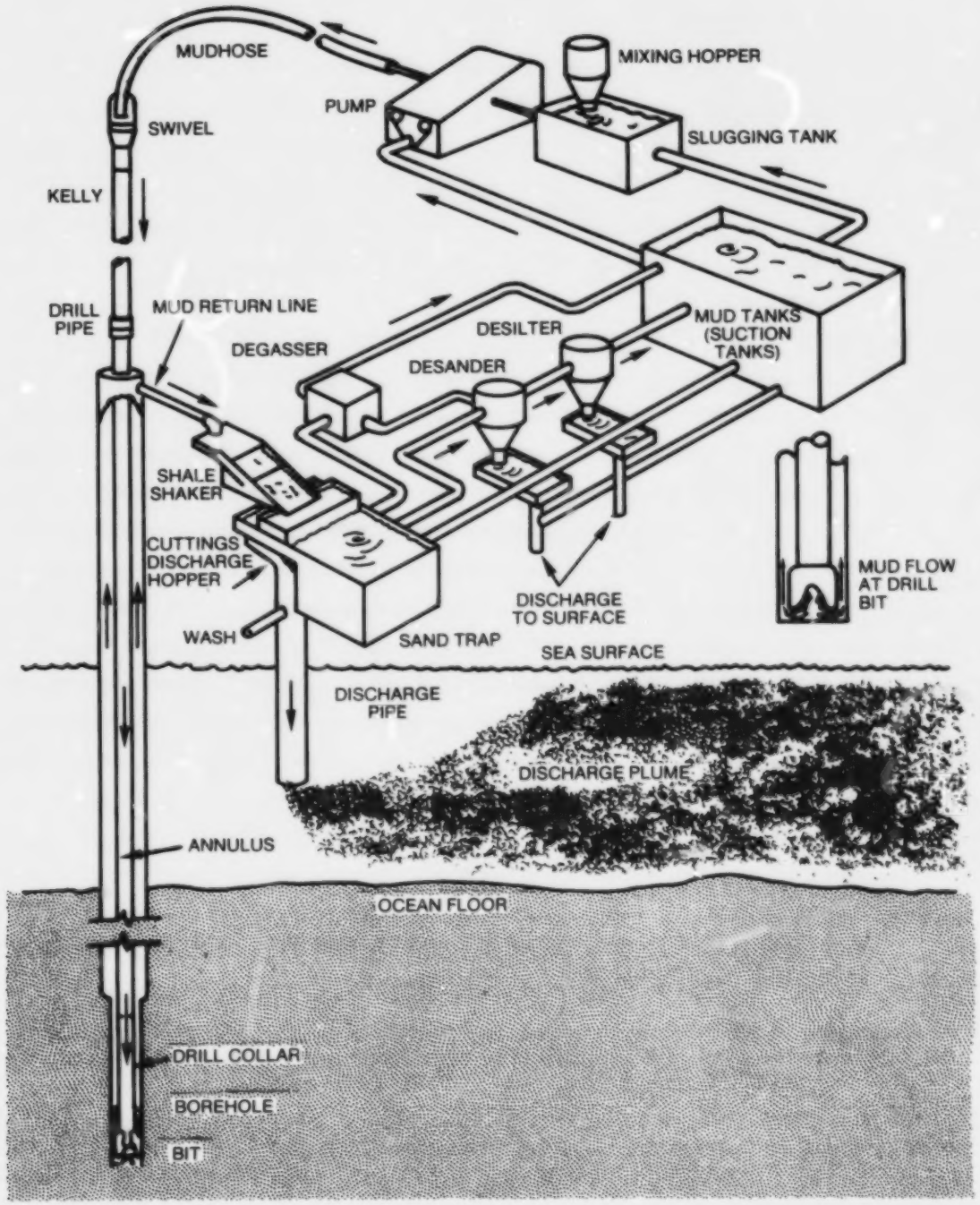

FIGURE 3 DRILLING FLUID SYSTEM OFFSHORE (Ray, 1982)

3. Diesel fuel should not be used as a spotting fluid for stuck pipe or as a lubricant in water-based mud. Alternate low toxicity oils should be present onboard for that purpose.

4. Where oil-based mud is used the bulk discharge of mud is prohibited under present guidelines (COGLA, 1986) except in emergency situations where the safety of personnel is at risk.

5. All oil-based mud systems should use low toxicity base oils with an aromatic hydrocarbon content of less than 5% with no 4 to 7 ring polycyclic aromatic hydrocarbons.

6. Base oils used in oil-based mud should be non-acutely lethal in 96-h tests of the 100% water soluble fraction (Appendices 2 and 4), and the whole mud should be non-toxic to 50% of the test organisms in 96-h volume for volume tests at a concentration of 100 000 mg/L.

7. The mean oil concentration on discharged cuttings should be 15 g oil/100 g dry cuttings or less. Any single sample should not exceed 30 g/100 g. Representative samples from the discharge point should be analysed for oil content according to the protocol in current COGLA guidelines.

8. Where a choice exists, the operator should select the least toxic of potential additives to a drilling mud system.

4.5 Design Opportunities

No significant advances have been made in the separation of mud and cuttings in recent years. Where opportunities arise to incorporate new and improved equipment in the solids control technology designers and operators should take advantage of these opportunities to improve both the retrieval of mud and the quality of discharges.

The problem of cold returning mud where oil-based mud is used and the separation of oil from the cold cuttings may be corrected or improved by the installation of a pre-heater before the shale shakers.

5 BALLAST WATER

5.1 Definition

Ballast water is defined for the purpose of this Code as all water used in floating exploration and production platforms, gravity base platforms and in transport or storage tankers for the purpose of stabilizing the vessel or controlling draft.

5.2 Source and Characteristics

Ballast water at offshore locations can consist of either fresh or salt water loaded on tankers at the refinery site, salt water loaded on tankers during the voyage to the offshore site or at the site as well as exploration and production platform ballast water. Ballast water may be clean, in segregated storage tanks, or heavily contaminated with oil from product storage tanks. Concentrations of oil in unsegregated ballast water in the North Sea range from 1000 to 3000 mg/L free oil. The prime difference between ballast water and storage displacement water is that ballast water can be contaminated with a range of oils from crude to highly refined products.

The discharge of tanker ballast water is characterized by intermittent high flows over short periods of time.

5.3 Treatment Options

The treatment of ballast water is performed in the same manner as storage displacement water and the reader is referred to Section 3.3 for that discussion. Additional treatment may be required in the near future to meet MARPOL* 73/78 (IMO, 1986) standards of 15 mg/L for vessels over 400 tonnes.

5.4 Recommended Practice

The following is recommended for the treatment and disposal of ballast water at offshore exploration and production facilities in Canada:

1. All proposed production and exploratory platforms, very large crude carrier storage vessels and shuttle tankers should be designed with segregated ballast tanks. This will eliminate the discharge of contaminated ballast water and ensure that these vessels meet MARPOL 73/78 (IMO, 1986) requirements for ballast discharges (15 mg/L).
2. All older vessels should meet MARPOL 73/78 (IMO, 1986) standards for oil discharges (15 mg/L), through the effective treatment of ballast water.

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* MARPOL 73/78 - an international agreement for the prevention of marine oil pollution, developed by the International Marine Organization (MARPOL stands for Marine Pollution).

6 SANITARY AND DOMESTIC WASTES

6.1 Definition

For the purpose of this Code, sanitary wastes are defined as all human body wastes and are commonly referred to as black water. Domestic wastes are defined for the purposes of this Code as all liquid wastes emanating from kitchens, laundry rooms, showers and wash basins and are commonly referred to as grey water.

6.2 Sources and Characteristics

Sanitary and domestic waste flow rates and characteristics are known and can be predicted using engineering rules of thumb based on cubic metres per capita per day discharge rates and kilograms per capita per day for constituent loadings (Table 5). Discharge rates for sanitary wastes range from 4 to 15 m^3/day for the average facility. Domestic wastes vary considerably because of the wide range in the use of shower water. Typical discharge rates are in the range of 5 to 10 m^3/day.

TABLE 5 SANITARY AND DOMESTIC WASTE FLOW RATES AND CONSTITUENT LOADINGS (Hooper and Myrick, 1971; Manning et al., 1974; Train et al., 1976)

		Loadings		Concentrations		
	Discharge Rate (m^3/cap·d^{-1})	BOD (kg/cap·d^{-1})	SS (kg/cap·d^{-1})	BOD (mg/L)	SS (mg/L)	Residual Chlorine (mg/L)
Sanitary Waste (treated)	0.075	0.002	0.003	30	40	1.7
Domestic Waste	0.11	0.022	0.016	195	140	0

6.3 Treatment Options

The treatment of sanitary waste is intended to reduce the biological oxygen demand (BOD) and the total suspended solids (SS) discharged. The addition of chlorine as a desinfectant reduces the probability of pathogenic bacteria being associated with the discharge. This can be achieved through the use of a secondary treatment system and the

addition of a disinfectant prior to discharge. At present, rotating biological contactors have demonstrated the highest reliability in northern waters. Other systems are in use at offshore sites and these systems may handle the waste treatment requirements of any one platform. The most common technology in use is the extended aeration unit although the activated sludge unit is also used. The quantity of sludge produced by these systems depends on the loadings and operation.

Domestic waste is normally macerated to reduce floatables and discharged without treatment.

6.4 Recommended Practice

The following is recommended for the treatment and disposal of sanitary and domestic wastes at offshore exploration and production platforms:

1. Permanently manned facilities should be designed to provide secondary treatment for sanitary wastes.
2. The minimum requirement for facilities operating in water depths greater than 20 m is maceration of wastes to a design particle size of 6 mm prior to discharge.
3. Facilities operating in water less than 20 m may require disinfection following secondary treatment to ensure protection of sensitive environments and water quality standards. Disinfection is not considered necessary in deeper waters.
4. Where disinfection is used the residual chlorine should not exceed 0.5 mg/L.
5. Secondary treatment systems with high efficiency and operating reliability under expected operating conditions and climate should be selected.

7 DECK DRAINAGE

7.1 Definition

Deck drainage is defined for the purpose of this Code to include all water (salt and fresh) resulting from precipitation, platform washings, deck washings, tank and equipment cleaning operations, runoff from curbs, gutters and drains including drip pans and work areas (U.S. EPA, 1982).

7.2 Sources and Characteristics

The discharge rate and volumes of deck drainage are dependent on the size of the platform, frequency of wash-down operations, and rainfall. The rate of precipitation and the area of exposed deck dictate the volume of discharge due to rainfall (Table 6). The mean exposed deck area of a production platform from this data is 2500 m^2 and the mean discharge rate is 25 m^3/cm of rainfall or 1% of exposed deck area. Discharge volumes from wash-down operations are difficult to estimate and depend on the frequency of wash-down operations, area washed and flow rate from hoses. The estimated total deck drainage from the proposed platform for the Hibernia field is between 27 and 150 m^3/d (Mobil Oil, 1985). Discharges from drip pans would be low in volume and intermittent.

TABLE 6 DECK DRAINAGE DISCHARGE DUE TO RAINFALL (Thomas et al., 1983)

Platform Type	Exposed Deck Area (m^2)	Drainage Discharge m^3/cm rain
small platform	125	1.3
6 pile platform	660	6.6
12 pile platform	1 050	10.5
8 pile gas platform	1 120	11.2
4 pile platform	1 240	12.4
8 pile oil platform	1 400	14.0
20 pile platform	1 425	14.3
jackup platform	2 225	22.3
28 pile platform	14 440	144.0
Mean	2 500	25.0
Median	1 220	12.2

Deck drainage can contain a number of contaminants which affect the quality of discharges or interfere with the efficiency of treatment systems. Wash-down chemicals include laundry detergents, dispersants and occasionally solvents. Jackson et al., (1981) reported use rates of these materials ranging from 5 to 2500 L per washing. The nature of oils that may drip onto a platform deck (refined oils with various additives) and the fact that detergents and solvents may be mixed with the oil means that deck drainage discharges can be expected to contain emulsified oil.

The spillage of drilling mud, including base oils and workover and completion fluids may cause deterioration in deck drainage quality (Train et al., 1976) as well as treatment system upsets due to solids loadings. Workover and completion fluids contain various acids but the effect of these acids on final pH is minimal due to dilution in the system.

7.3 Treatment Options

The level of treatment for deck drainage varies but the majority of operators in the North Sea, Gulf of Mexico and Cook Inlet use a skim tank or cone bottom separator for treating deck drainage. This system may be combined with a skim pile for additional oil recovery during disposal. The skim tank separates oil by gravity; therefore, retention time in the tank is an important factor in achieving acceptable discharge levels. Arnold (1983) indicated that 30 minutes is an adequate residence time for separation to occur. In Cook Inlet the residence time for skim tanks ranges from 2 to 24 hours (U.S. EPA, 1985). The performance of skim tanks is limited to insoluble oil with a droplet size <150 mm (Thomas et al., 1983).

The treatment of deck drainage can be complicated by the presence of various detergents and emulsifiers used to clean decks. This problem can be overcome by the separation of deck drainage resulting from wash-downs and rainfall from machinery oil losses. Segregated drains are common in the industry, with collected liquids treated separately. Milne and Greene (1985) note that a typical Gulf of Mexico treatment system segregates oil from drip pans under machinery into a closed oil recovery tank. Washdown and rainfall drainage is directed via an open drain system to a skim tank. Deck drainage is occasionally mixed with other oily water such as produced water for treatment. This can cause problems in the treatment system. Some of the problems encountered with mixing of deck drainage and other oily wastes for treatment are:

1. Extreme flow rate variations in deck drainage cause surges in produced water systems that cause upsets.
2. The mixing of oxygenated water with produced water can cause the formation and precipitation of suspended solids which foul treatment systems.
3. Detergents from deck washings cause emulsification of oil and lead to serious upsets in produced water and ballast/displacement water treatment systems.

A variety of oil/water separators have been designed for the shipping industry to meet MARPOL standards for the discharge of oily waste water but these systems are not in common use on oil and gas exploration and production platforms as yet. Usually, these systems utilize a filtration media which removes insoluble oil and emulsified oil.

7.4 Recommended Practice

The following is recommended for the treatment and disposal of deck drainage at offshore exploration and production facilities in Canada:

1. Deck drainage from wash downs and rainfall should be directed to a separate drain system from that collected from drip pans placed under machinery.
2. Deck drainage treatment systems should be designed to meet MARPOL 73-78 discharge limits of 15 mg/L oil.
3. Deck drainage should be treated separately and not mixed with other oily waste streams.
4. Treated water should be discharged below the surface, preferably through a skim pile and additional oil collected.
5. Oily residues from treatment should be incinerated on site or shipped ashore for disposal in an environmentally acceptable way.

8 COOLING WATER

8.1 Definition

Cooling water is defined for the purposes of this Code as once through non-contact water used to cool machinery or as a heat exchange medium for cooling during the processing of oil and gas.

8.2 Source and Characteristics

Cooling water is extracted from the surrounding ocean and therefore is identical in composition to the sea water at the drilling site. Discharged cooling water, however, can have an elevated temperature as high as 30°C (Mobil Oil, 1985). Discharged cooling water also may contain small quantities of biocide used to control biofouling. The most common biocide is chlorine and quantities used vary.

The volume of cooling water used will depend on the type and size of the equipment on the platform and the ambient temperature. Mobil Oil (1985) estimated that 10 000 m^3/day will be used per rig during development drilling at Hibernia and 180 000 m^3/day will be used during production.

8.3 Recommended Practice

The following is recommended for disposal of once through non-contact cooling water from offshore exploration and production facilities in Canada:

1. If chlorine is used as a biocide:
    a) the minimum amount of chlorine demonstrated to be effective should be used; and
    b) the total residual chlorine level at the discharge point should not exceed 0.5 mg/L.
2. If other biocides are used:
    a) these chemicals should be approved by the regulator; and
    b) biocides having carcinogenic, mutagenic effects or a residence time in the environment in excess of a few hours (<24) should be avoided.
3. Where possible cooling water should be used as makeup for the injection water system.
4. Discharge should be at or near the surface to increase degradation of the biocide by ultraviolet light.

9 PRODUCED SAND

9.1 Definition

Produced sand is defined for the purpose of this Code as all solids recovered from the formations with crude oil or gas and may form either the suspended solids loading of discharge water or a separate solid waste.

9.2 Sources and Characteristics

The quantity of produced sand is dependent upon the age of the well and the formation characteristics. Low volumes of sand occur at the early stages of development and larger volumes are produced as the wells are depleted (Maer, 1975). If low volumes of fine sands are produced they may be carried through the oily water treatment system and appear as suspended solids in the produced water effluent, while high volumes of coarse particles may be removed in cyclone separators and thus produce a solid waste (Maer, 1975; Train et al., 1976). Typical maximum produced sand discharge rates range from 4 to 40 m^3/day (Maer, 1975). Mobil Oil (1985) estimates the produced sand from the Hibernia field will range from < 1 m^3/day to several m^3/day. All produced sand collected will be contaminated with crude oil to varying degrees depending on the characteristics of the crude.

9.3 Treatment Options

Produced sand collected from cyclone separators requires treatment to reduce the oil content prior to disposal. The sand is usually washed with water and detergents or solvent to recover oil and is reported to contain < 1 mg/kg of oil (Garcia, 1974) after washing. The oil/water portion is directed to the heater treater to break emulsions and recover the oil.

9.4 Recommended Practice

The following is recommended for disposal of produced sand at offshore exploration and production facilities Canada:

1. Produced sand containing < 1 mg/kg total oil can be discharged directly to the ocean.

10 WELL COMPLETION AND WORKOVER FLUIDS

10.1 Definition

Well completion fluids are defined for the purposes of this Code as those chemicals and solids used to prepare a well for production of hydrocarbons after drilling is complete. Workover fluids are defined as those chemicals and solids used to enhance oil or gas production from a producing well when hydrocarbon flow has slowed.

10.2 Sources and Characteristics

Every production well drilled will be prepared for use with specially formulated completion fluids. Completion fluids mainly involve suspension of clay in fresh water or oil, diesel fuel, crude oil and high density salt solutions, treated with special chemicals to control flow properties and mitigate corrosion.

Workover fluids are similar to completion or drilling fluids, and frequently there is no clear difference between them. Their composition is designed to minimize damage to the producing zone and may include a mixture of clay in water or oil, salt water and various chemical additives. In conjunction with workover or completion operations the producing zone may be stimulated with acid. After finishing workover or completion operations, the well is cleaned by pumping fluids to a tank prior to switching flow to the production facilities.

10.3 Treatment Options

The main problem with returning completion and workover fluids is the high acid content. Acidity should be neutralized prior to disposal.

10.4 Recommended Practice

The following is recommended for the treatment and disposal of completion and workover fluids at offshore exploration and production facilities in Canada:

1. Slugs of completion and workover fluids returned to the surface should be collected and treated separately to avoid upsets in the produced water treatment system.
2. Spent acids should be neutralized prior to disposal.
3. Neutralized acids may be discharged directly to the ocean.

11 DESALINATION BRINES

11.1 Definition

Desalination brines are defined for the purposes of this Code as the concentrated brine produced from the production of potable water from salt water at offshore facilities.

11.2 Sources and Characteristics

The chemical composition of these brines is the same as sea water except that it is approximately twice as concentrated as sea water. The volumes discharged range from 20 to 30 m^3/day (Milne and Greene, 1985).

11.3 Treatment Options

The treatment of desalination brines is limited to dilution prior to discharge. In most jurisdictions there is no requirement for treatment of desalination brines prior to disposal.

11.4 Recommended Practice

The following is recommended for disposal of desalination brines at offshore exploration and production facilities in Canada:

1. Desalination brines may be discharged directly to the ocean without treatment or pre-dilution except in areas sensitive to salinity changes.

12 COMBUSTIBLE WASTES

12.1 Definition

Combustible wastes are defined for the purpose of this Code as all wastes that can be incinerated on site at offshore facilities.

12.2 Sources and Characteristics

Some examples of these wastes are: paper, plastics, combustible kitchen waste, and oily rags. The volumes produced are variable and no figures are available for this waste stream alone.

12.3 Treatment Options

Few options exist for the treatment prior to disposal of combustible waste other than compaction to reduce volume. There are, however, at least two options for disposal. Compacted waste can be transported to shore for disposal in an approved landfill or incinerator or the waste can be incinerated offshore. A common practice is to use a burn basket; however, the operation of burn baskets is dependent upon wind conditions and results in the deposit of ash and partly combusted material into the sea as well as presenting a fire hazard. A better option is incineration in an onboard fuel-fired incinerator, which would provide better control in areas where open flame may be a problem.

12.4 Recommended Practice

The following is recommended for disposal of combustible waste at offshore exploration and production facilities in Canada:

1. Combustible waste may be burned on-site in fuel-fired incinerators or burn baskets or compacted and shipped to shore in closed containers for disposal in an approved landfill site or incinerator.
2. Burn baskets should not be used for disposal of plastics, kitchen waste or oily waste.
3. Residue from incineration should be shipped to shore for disposal in an approved landfill site.

13 NON-COMBUSTIBLE WASTES

13.1 Definition

Non-combustible wastes are defined for the purpose of this Code as all waste that cannot easily be incinerated on-site, such as glass and metal.

13.2 Sources and Characteristics

There are no readily available data on non-combustible waste volumes since this waste stream is variable. Non-combustible wastes are normally generated from repair and maintenance work on machinery. The materials included as waste can range from residues from incineration to drill pipe. The majority of material would be scrap metal.

13.3 Treatment Options

Non-combustible wastes are not easily treated on-site at offshore facilities. The generally accepted practice is to package this waste and ship it to shore for disposal. The option of ocean dumping , although not used yet in Canada, could be considered.

13.4 Recommended Practice

The following is recommended for disposal of non-combustible wastes at offshore exploration and production facilities in Canada:

1. Non-combustible wastes should be packaged in closed containers and shipped to shore for recycling or disposal at an approved site.
2. Ocean dumping of non-combustible wastes may be considered a viable option and must comply with the Ocean Dumping Control Act and other relevant legislation.

14 FIRE CONTROL SYSTEM TEST WATER

14.1 Definition

Fire control system test water is defined for the purpose of this Code as all water used in fire hoses during the regular testing of these devices.

14.2 Sources and Characteristics

The water used in fire control system testing is extracted directly from the sea and does not differ from sea water except that a biocide may be added to control biofouling in pumps and hoses. The range in volumes used is large and can vary from 10 m^3 to 65 000 m^3/day (Thomas et al., 1983).

14.3 Treatment Options

Fire control test water does not usually receive any treatment prior to discharge directly to the ocean.

14.4 Recommended Practice

The following is recommended for disposal of fire control test water at offshore exploration and production facilities in Canada:

1. Fire control test water may be discharged directly to the ocean without treatment.
2. Addition of biocide to reduce biofouling should be minimal. If chlorine is used then the residual chlorine should be 0.5 mg/L or less.
3. The biocide used should be approved by the regulator.

15 CHEMICAL ADDITIVES

15.1 Definition

Chemical additives are defined for the purpose of this Code as all chemicals and compounds used on an offshore platform in the preparation of drilling fluids, added to injection water, used in the processing of oil and gas, or added to intake or discharge streams for biofouling or corrosion protection.

15.2 Sources and Characteristics

A list of chemicals that can be used at an offshore exploratory or production facility is published by Oil Week each year. Any of the more than 700 chemicals listed may be used offshore, although the drilling of a single well may only require the use of a few. In 1983, 67 of these products were used in the drilling of exploratory wells north of 60° in Canada (Evans and Milburn, 1985).

A variety of chemicals are used in almost every process on an offshore platform from the production of potable water to the treatment of injection water. The quantity used is dependent upon the need and estimates are not available for the amount discharged to the ocean. Evans and Milburn (1985) compiled a list of materials used in drilling mud in the Canadian Arctic from 1978 to 1982 which includes the quantity and use rate of each chemical. Some of the chemicals used are lost to the formations others are consumed in the process for which they are utilized, while others are discharged.

15.3 Treatment Options

The majority of the chemicals used cannot be treated by conventional means. The best approach is to limit use to the minimum amount needed to achieve the desired objective. The use of chemicals can also be monitored through a chemical notification system which would require disclosure of all chemicals to be used, the rate of use and the appropriate toxicity data. Where there is a choice of chemicals the least toxic should be selected. The use of very toxic or persistent chemicals may be prohibited or restricted to uses where their release to the environment is not possible.

15.4 Recommended Practice

The following is recommended for the control of chemical additives on offshore exploration and production facilities in Canada:

1. A chemical notification scheme should be established to monitor the use of chemicals at offshore facilities (see Appendix 1).
2. A list of approved chemicals should be developed based on a chemical notification scheme which should be used by regulatory agencies in evaluating proposed chemical uses.
3. Regular inspections should be conducted by the regulatory agency to ensure industry compliance.

16 ABANDONMENT

16.1 Definition

Abandonment is defined for the purpose of this Code as any activity related to the shut down, either temporarily or permanently, of an offshore production facility.

16.2 Sources and Characteristics

The liquid and solid discharges at the time of abandonment cover the whole range of discharges discussed in the Code plus the solid waste associated with the removal of equipment. The quantity of solid waste associated with abandonment, while dependent on the mode of production, cannot be predicted with any accuracy at this time because of the lack of abandonment activity which has occurred to date.

16.3 Treatment Options

The options for treating and disposing of wastes at the completion of production of an oil and gas field requires that a plan be formulated to handle the additional wastes generated from decommissioning and the reduction in the efficiency of installed waste treatment systems with the reduction in flows.

Ocean dumping of solid wastes may be a viable option and injection of liquid wastes into spent formations should also be considered. The plan for the treatment and disposal of wastes should take into consideration the use of the area after the completion of the abandonment procedures. Several pieces of Canadian legislation (e.g., Canada Shipping Act, Ocean Dumping Control Act, Navigable Waters Protection Act, Arctic Water Pollution Prevention Act and Canada Oil and Gas Act) have a bearing on the extent of cleanup required after abandonment. The operator should be aware of the applicable local legislation that affects abandonment plans.

16.4 Recommended Practice

The following is recommended for the abandonment of oil and gas production facilities at offshore locations in Canada:

1. A decommissioning plan should be incorporated as part of the development plan approval process.
2. The plan should be negotiated between industry and the agencies involved in the approval of the development plan in consultation with those agencies with a mandate to manage the fisheries and environment after abandonment.

3. Where possible, all liquid wastes should be injected into depleted formations and all physical impediments to fishing or other legitimate uses should be removed.

4. If wastes cannot be injected into spent formations, then they may be disposed of in a manner approved by the regulator.

17 SUMMARY OF RECOMMENDATIONS

The following summary of recommendations is presented to assist the user in identifying the preferred methods of treatment and disposal and to provide a quick reference to the page and section number which contains the discussion leading to the recommendations.

Produced Water (Section 2, page 3)

1. Produced water re-injection should be investigated at all production sites where water injection for pressure maintenance may be part of the development plan. In shallow water or near ecologically sensitive habitats, produced water re-injection is considered to be the best option for protection of the environment.
2. Produced water treatment systems for offshore should be designed to achieve a monthly mean oil concentration of 25 mg/L or less.
3. If the monthly mean oil concentration exceeds 40 mg/L, excluding treatment system upsets, a detailed report must be submitted to the regulator stating the reasons for the exceedence, including influent and effluent data, and the corrective action taken to achieve compliance.
4. Treated produce water, if discharged, should be released at a depth which will allow maximum dispersion.

Storage Displacement Water (Section 3, page 8)

1. Treatment systems for storage displacement water should be designed to achieve a monthly mean effluent oil concentration of 25 mg/L or less.
2. Discharge of the oil/water interface layer should be avoided. If for some reason the interface layer must be discharged, it should be pumped with oil to the export tanker or pipeline.
3. Sludge from the periodic cleaning of storage cells should be recovered and shipped to shore for disposal or recycling or incinerated on site.

Drilling Fluids and Cuttings (Section 4, page 11)

1. Well maintained and operated standard solids control equipment, consisting of shale shakers, desanders and desilters should be considered as best practicable technology for the separation of cuttings from mud for water-based mud.
2. If the bulk discharge of water-based mud is necessary at the completion of a well, it should be performed in a manner which ensures that the solids portion of the mud is restricted to the same area as the cuttings and that maximum dispersion of the liquid fraction is achieved.
3. Diesel fuel should not be used as a spotting fluid for stuck pipe. Alternate low toxicity oils should be present on board for this purpose.
4. Where oil-based mud is used the bulk discharge of mud is prohibited under present guidelines (COGLA, 1986) except in emergency situations where the safety of personnel is at risk.

5. All oil-based mud systems should use low toxicity base oils with an aromatic hydrocarbon content of less than 5%; with no 4 to 7 ring polycyclic aromatic hydrocarbons.

6. Base oils used in oil-based mud must be non-acutely lethal in 96-h tests of the 100% water soluble fraction (Appendices 2 and 4), and whole mud should be non-toxic to 50% of the test organisms in 96-h volume for volume tests at a concentration of 100 000 mg/L.

7. The mean oil concentration on discharged cuttings should be 15 g oil/100 g cuttings or less. Any single sample should not exceed 30 g/100 g. Representative samples from the discharge point should be analysed for oil content according to the protocol in current guidelines.

8. Compounds and chemicals anticipated for use in a drilling fluid system should be approved for use under a Chemical Notification Scheme (Appendix 1).

9. Where a choice exists, the operator should select the least toxic of potential additives to a drilling mud system.

Ballast Water (Section 5, page 15)

1. All proposed production and exploratory platforms, very large crude carrier storage vessels and shuttle tankers should be designed with segregated ballast tanks. This will eliminate the discharge of contaminated ballast water and ensure that these vessels meet MARPOL 73/78 requirements for ballast discharges (15 mg/L).

2. All older vessels should meet MARPOL 73/78 standards for oil discharges (15 mg/L), through the effective treatment of ballast water.

Sanitary Wastes (Section 6, page 16)

1. Permanently manned facilities should be designed to provide secondary treatment for sanitary wastes.

2. The minimum requirement for facilities operating in water depths greater than 20 m is maceration of wastes to a design particle size of 6 mm prior to discharge.

3. Facilities operating in water less than 20 m may require disinfection following secondary treatment to ensure protection of sensitive environments and water quality standards. Disinfection is not considered necessary in deeper waters.

4. Where disinfection is used the residual chlorine should not exceed 0.5 mg/L.

5. Secondary treatment systems with high efficiency and operating reliability under expected operating conditions and climate should be selected.

Deck Drainage (Section 7, page 18)

1. Deck drainage from wash downs and rainfall should be directed to a separate drain system from oil collected from drip pans placed under machinery.

2. Deck drainage treatment systems should be designed to meet MARPOL 73/78 discharge limits of 15 mg/L oil.

3. Deck drainage should be treated separately and not mixed with other oily waste streams.

4. Treated water should be discharged below the surface, preferably through a skim pile and additional oil collected.
5. Oily residues from treatment should be incinerated on site or shipped ashore for recycling or disposal.

Cooling Water (Section 8, page 21)

1. If chlorine is used as a biocide:
   a) the minimum amount of chlorine demonstrated to be effective should be used; and
   b) the total residual chlorine level at the discharge point should not exceed 0.5 mg/L.
2. If other biocides are used:
   a) these chemicals should be approved by the regulator; and
   b) biocides having carcinogenic, mutagenic effects or residence time in the environment in excess of a few hours should (< 24) be avoided.
3. Where possible cooling water should be used as makeup for injection water.
4. Discharge should be at or near the surface to increase degradation of the biocide by ultraviolet light.

Produced Sand (Section 9, page 22)

1. Produced sand containing < 1mg/kg total oil may be discharged directly to the ocean.

Completion and Workover Fluids (Section 10, page 23)

1. Where possible slugs of completion and workover fluids returned to the surface should be collected and treated separately to avoid upsets in the produced water treatment system.
2. Spent acids should be neutralized prior to disposal.
3. Neutralized acids may be discharged directly to the ocean.

Desalination Brines (Section 11, page 24)

1. Desalination brines may be discharged directly to the ocean without treatment or pre-dilution.

Combustible Waste (Section 12, page 25)

1. Combustible waste may be burned on site in fuel-fired incinerators or burn baskets or compacted and shipped to shore in closed containers for disposal in an approved landfill site or incinerator.
2. Burn baskets should not be used for disposal of plastics, kitchen waste or oily waste.
3. Residues from incineration should be shipped ashore for disposal in an approved landfill site.

Non-Combustible Waste (Section 13, page 26)

1. Non-combustible wastes should be packaged in closed containers and shipped to shore for disposal or recycling.
2. Ocean dumping of non-combustible wastes may be considered a viable option and must comply with the Ocean Dumping Control Act and other relevant legislation.

Fire Control Test Water (Section 14, page 27)

1. Fire control test water may be discharged directly to the ocean without treatment.
2. Addition of biocide to reduce biofouling should be minimal. If chlorine is used then the residual chlorine should be 0.5 mg/L or less.
3. The biocide used should be approved by the regulator.

Chemical Additives (Section 15, page 28)

1. A chemical notification scheme should be established to monitor the use of chemicals at offshore facilities (see Appendix 1).
2. A list of approved chemicals should be developed based on the chemical notification scheme which can be used by regulatory agencies in evaluating proposed chemical uses.
3. Regular inspections should be conducted by the regulatory agency to ensure industry compliance.

Abandonment (Section 16, page 30)

1. A decommissioning plan be incorporated as part of the development plan approval process.
2. The plan should be negotiated between industry and the agencies involved in the approval of the development plan in consolidation with those agencies with a mandate to manage the fisheries and environment after abandonment.
3. Where possible, all liquid waste should be injected into depleted formations and all physical impediments to fishing should be removed.
4. If wastes cannot be injected into spent formations, then they may be disposed of in a manner approved by the regulator.

18 COMPLIANCE MONITORING

18.1 Definition

Compliance monitoring is defined for the purpose of this Code as the regular sampling and analysis of all effluent streams to determine the concentration and or quantities of specific elements and compounds and their compliance with the regulated levels of these materials.

18.2 Characteristics

The primary purpose of a compliance monitoring program is to determine if the effluent streams from the facility are within the regulated levels and where problems are identified to take corrective action. This can only be achieved if the operator is fully aware of the requirements of the regulations and is committed to a regular review of monitoring results. The program must also be combined with a regular maintenance schedule to ensure that equipment used to treat effluents is working at optimum levels.

The level of effort applied to compliance monitoring may change over time. A new production platform will require more effort on the part of the operator into compliance monitoring than a long established platform. The operator of a new production facility will need to know how well its pollution control equipment is working and where and when the equipment does not work to the desired levels. This kind of information can only be obtained by frequent sampling and analysis. The regulator is also interested in the level of control afforded by the pollution equipment and therefore frequent consultation and transmittal of data is required. When the program has begun to show established patterns of performance then the frequency of sampling and reporting can be adjusted to meet the need of both the regulator and the operator. Alternatively, influent stream characteristics will change during the life of the field. Close attention will be required whenever such changes result in significant changes in influent characteristics of a treatment facility.

To be truly effective a compliance monitoring program operated by the industry should be audited on a regular basis by the regulator. The audit should include both an analysis of the records of the operator and a detailed sampling and analysis of effluents by the regulator for comparison to the operator's records.

18.3 Recommendations

The following is recommended for a minimum level of monitoring at offshore production and exploration facilities in Canada:

1. Produced Water: influent and effluent concentrations and flows at each stage of treatment should be sampled twice per day for:

   a) total oil; and
   b) total aromatic hydrocarbons.

2. Storage Displacement Water: influent and effluent concentrations and flows at each stage of treatment should be sampled twice daily during discharge for:

   a) total oil; and
   b) total aromatic hydrocarbons.

3. Drilling Fluids and Cuttings: effluent concentrations and flows should be determined for cuttings at the end of the shale shaker, desanders and desilters, or after washing for:

   a) percent mud on cuttings;
   b) particle size; and
   c) oil content.

   Prior to bulk discharge of water-based mud the acute toxicity of the water soluble fraction should be determined.

4. Ballast Water: influent and effluent concentrations and flows should be determined at each stage of treatment twice daily during discharge for total oil.

5. Sanitary Waste: Effluent concentrations should be determined once daily for:

   a) particle size; and
   b) residual chlorine.

6. Deck Drainage: influent and effluent concentrations and flows should be determined once daily for total oil.

7. Cooling Water: effluent concentrations and flows should be determined once daily for residual chlorine.

8. Produced Sand: effluent concentrations and flows for total oil should be determined daily when there is sufficient material to produce a solid waste.

9. Combustible Waste: record of the total volume produced on a daily basis should be made and the proportion incinerated on site recorded.

10. Non-Combustible Waste: record of the total volume and general composition should be made.

11. Reporting and Auditing: the operator should report the results of monitoring to the regulatory agency at least every three months where compliance monitoring has indicated that the facility is in compliance. Where the operation has exceeded the regulated limits for a specific discharge the regulator may require more frequent reporting (e.g., produced water where the monthly average exceeds 40 mg/L for oil) auditing of compliance by the regulator should mirror the reporting schedule.

12. Analytical Methods: analysis for oil content should be performed by infrared spectrophotometry. This allows the operator to install automatic sampling and analysis equipment and reduce the number of personnel required to conduct monitoring. All other analysis should be performed by ASTM methods and/or by a method approved by the regulator.

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APPENDIX 1

CHEMICAL NOTIFICATION SCHEME (1) FOR THE SELECTION OF CHEMICALS(2) USED OFFSHORE

APPENDIX 1 CHEMICAL NOTIFICATION SCHEME(1) FOR THE SELECTION OF CHEMICALS(2) USED OFFSHORE

Wherever possible, the use of chemicals which are highly toxic to marine organisms and/or tend to persist in the environment and which are likely to be discharged should be avoided. In particular, the use of materials based on any of the following should be avoided: Mercury, Cadmium, Cyanide, Organo-tin, Organophosphorus and certain persistent Organo-halogens such as PCBs and Chlorophenols. Chemicals containing Arsenic, Lead, Copper, Zinc, Beryllium, Nickel, Vanadium or Chromium should be avoided if their use (either singly or in combination) is likely to result in the discharge at concentrations in excess of 100 mg/L.

Where chemicals containing these elements are used and are likely to be discharged, the information below should be made available to the regulatory agency.

a. details of the approximate scale of use of the chemical and the expected discharge pattern;
b. outline of the physical properties of the chemical;
c. outline of the chemical composition of the material; and
d. acute toxicity to marine species of the product as supplied to the operator.

Following receipt of the information requested the regulatory agency will place the product in a category. These categories are based on the toxicity of the products as indicated by the 96-h LC_{50} and take some account of their composition and use.

These categories indicate the amount of product which, on the basis of its toxicity, composition and probable use pattern, can be expected to be used without serious environmental effects. They, therefore, indicate the quantities that can be used before the regulatory agency must be informed.

Category 1 - Notification of all discharges.

Category 2 - Notification of discharges in excess of 1 tonne per installation per year.

Category 3 - Notification of discharges in excess of 10 tonnes per installation per year.

Category 4 - Notification of discharges in excess of 100 tonnes per installation per year.

A model form based on the U.K. scheme is attached for the presentation of this information. Chemicals in this context include all materials supplied in liquid, granular or powder form.

Category 5 - Notification of discharges in excess of 1000 tonnes per installation per year.

Category 6 - No notification required for any quantity discharged.

It is not intended that this procedure should cover the following materials whose discharge:

1. may be prohibited under existing legislation (e.g., crude oil, fuel oil including all forms of diesel fuel, oil refuse and refined products) or

2. anticipated to have little environmental impact on the scale at which they are discharged:

    a) cement, sand gravel;
    b) clay, bentonite, barite, calcium carbonate and other virtually inert solids;
    c) phosphate based inorganic dispersants;
    d) starch and cellulose formulations containing no biocide; and
    e) inorganic acids and alkalis used in mud formulations mainly for pH control modifications.

Manufacturers/suppliers should submit the requested information on their products to the regulatory agency using the attached form (even if no toxicity data is available). A list of chemicals on which full or partial notification has been received will be circulated to operators at regular intervals.

It may be necessary in certain circumstances to discharge chemicals on a scale that could cause adverse environmental effects (i.e., the discharge exceeds the limit for the category). Where such use is proposed, the operator should undertake prior consultation with the Regulatory Agency. On the basis of these consultations the government may wish to advise on the proposed discharge or the mode of disposal of the spent chemical and/or to press for the introduction of substitutes within an agreed time period.

The scheme is administered by the Regulatory Agency but involves consultations with other departments and particularly Environment Canada and Fisheries and Oceans Canada.

MODEL PROFORM A

NOTIFICATION SCHEME: CHEMICALS FOR USE IN OFFSHORE OIL OPERATIONS

To assess the general acceptability of a product of use, it is necessary to obtain details of its composition together with data on its toxicity to marine organisms. The following information is required:

PRODUCT

1. Name of product:.....

2. Nature of product:.....

USE

3. Method of use:.....
.....

4. Probable scale of use:
   (i) tonnes/yr:.....
   (ii) kg/day:.....

5. Probable scale of discharge containing the product:
   (i) frequency:.....
   (ii) volume:.....
   (iii) duration:.....

6. Amount of product discharges (kg/day or kg/discharge):.....

PHYSICAL PROPERTIES

7. Please state whether liquid:.....solid:.....
   or mixture:.....
   (a) Specific gravity (liquid:.....) (solid:.....)
   (b) Suspended solids (mg/L):.....
   (c) Dissolved solids (mg/L):.....
   (d) Where liquid state whether miscible:.....or immiscible:.....
   with seawater.
   (e) Solubility in seawater (mg/L):.....

CHEMICAL NATURE AND COMPOSITION

8. (i) Is the product BASED on any of the following (Yes/No):

Mercury:.....Cadmium:.....Cyanide:.....
Organo-tin compounds:.....Organophosphorus compounds:.....
Persistent Organo-halogen compounds:.....
(e.g., PCBs and Chlorophenols)

(ii) If the answer to any of the above is YES give the chemical form, units of concentration and whether the analysis is (a) on a dry weight or wet weight basis and (b) on a volume/volume, weight/weight or weight/volume basis.

.....
.....
.....

9. (i) Does the product contain LESS THAN 100 ppm of EACH of the following: Mercury, Cadmium, Arsenic, Copper, Zinc, Beryllium, Chromium, Nickel, Vanadium, (Yes/No):.....

(ii) If the answer to any of the above is NO and usage per user point could exceed 1000 tonnes/yr (see 4) then give concentrations where they exceed 100 ppm.

.....
.....
.....
.....

10. Give the complete and precise composition of the product, including 'active', 'inert', solvent and additive ingredients and their proportions. (Recognized chemical formulae or recognized chemical names for all ingredients, please).

.....
.....
.....
.....
.....
.....

MARINE TOXICITY DATA

11. Note: if a test on one type of organism gives a 96-h LC_{50} greater than 1000 ppm then the test on a second type of organism is not required; if less than 10 ppm tests on both types are required in all cases. Between 10 and 1000 ppm further information may be required.

96-h LC_{50} to a marine fish (state species and whether as eggs, larvae, juveniles, or adults) .....

96-h LC_{50} to a marine crustacean (state species and whether as eggs, larvae, juveniles, or adults) .....

(a) What method used? (Static test, with toxin replacement, continuous agitation test, or continuous flow test) .....

(b) By whom and when were these tests carried out? .....

(c) Is a test report available? .....

12. Does the material degrade appreciably within 96 hours in the marine environment (Yes/No):.....

If YES (i) What is its half-life (h/day):.....

(ii) What is the 24-h LC_{50} to the species tested above:.....

48-h LC_{50} to the species tested above:.....

13. Is information available on the identity of the major breakdown products, or on the way in which the product breaks down over a period of greater than 96 hours.

14. Name and signature of certifying officer for the manufacturer, supplier or user:

Date.....

NOTIFICATION SCHEME FOR SELECTION OF CHEMICALS FOR USE OFFSHORE

LIST OF NOTIFIED CHEMICALS

NOTE: The presence of a product on this list does not imply a recommendation by the Regulatory Agency or any other Government agency of the product for its primary function.

Product	Comments
Listed under Supplying or Manufacturing Company	

APPENDIX 2

PROTOCOL FOR TOXICITY TESTING

LABORATORY PROCEDURE FOR DETERMINING THE ACUTE LETHALITY OF A WATER-SOLUBLE FRACTION OF MINERAL OIL TO RAINBOW TROUT

June 1985

Environmental Protection Service
Environment Canada, Atlantic Region
45 Alderney Drive
Dartmouth, Nova Scotia
B2Y 2N6

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1. INTRODUCTION

Oil-based drilling muds (OBM) are those in which oil is the carrier for all other mud activities and in which water or brine may be emulsified in the oil. These OBM are not usually discharged into the sea. The cuttings are removed with normal cuttings control equipment and discharged. The remaining OBM is reused or stored prior to disposal at a proper facility onshore. Diesel fuel has been the most common oil used in OBM systems particularly in the North Sea; however, a switch to mineral oils with a lower aromatic content is underway there, and is being considered in both Canada and the United States. These mineral OBM are expected to be less toxic to aquatic organisms than the diesel OBM because of the lower aromatic hydrocarbon content of the base oil.

There are several advantages to using OBM compared to using water-based drilling muds. Overall drilling times are reduced due to the increased lubricating qualities. The cost of the mud system is generally reduced due to the high stability of the OMB which allows them to be reused for longer periods with less daily makeup requirements (COGLA, 1984a).

In response to increased interest in using OBM in the Canadian offshore, COGLA developed interim guidelines for their use. In 1983, approval was given to use OBM on an experimental basis to drill the Shell PCI et al Alma F-67 well on the Scotian Shelf. The data from this experimental well, in conjunction with an industry-government workshop on OBM held in Ottawa in May 1984 (COGLA, 1984b), was used in the development of the more technical aspects of the interim guidelines.

Concurrent with these events, an intergovernmental Task Force was formed to develop formal environmental guidelines for the use of OBM in the Canadian offshore. As part of this exercise, EPS was requested to develop a bioassay protocol for screening the acute lethality of the base oils.

2. INTENT

This toxicity testing protocol is designed to screen all base oils prior to use in offshore drilling and to identify those products which are obviously more toxic to fish than other readily available products. This test protocol is not designed to determine long term or sub-lethal toxic effects on marine organisms. This test is a screening, single-species, lethality test, and is intended to be the first practical stage of a toxicity assessment to identify potential hazardous materials. More complex, long-term monitoring procedures with organisms found in the marine exploration areas may be required to investigate potential environmental impacts of using these OBM in offshore drilling.

3. FORMULATION OF THE WATER SOLUBLE FRACTION

These bioassays will be performed on the water soluble fraction (WSF) of the mineral oil. The procedure for the preparation of the test solutions follows that outlined in Anderson, et al. (1974). The WSF of each oil is prepared by placing 1 part mineral oil over 9 parts of freshwater in a 5-gallon glass jar which is sitting on a variable speed magnetic stirrer. The contents of the jar are stirred slowly so that the vortex extends approximately 25 percent of the distance from the surface to the bottom of the jar. The solution is stirred for 20 hours at room temperature (approximately 20°C). During stirring, the bottle is capped with aluminum foil to minimize the evaporation and loss of the more volatile oil hydrocarbons. After 20 hours, stirring is stopped and the oil and water phases are allowed to separate for four hours. The water phase is then siphoned off making sure that none of the surface oil is drawn off with the water. This is the 100 percent WSF test solution and bioassays on this solution are started within four hours.

4. GENERAL PROCEDURES FOR FISH BIOASSAYS

General procedures for fish bioassays are based on the Standard Procedure for Testing the Acute Lethality of Liquid Effluents (EPS, 1980). Some changes have been made to suit specific requirements of testing oils. It is believed that the use of the modified procedure will provide consistent and comparable bioassay results. Other reference material consulted for the development of the procedure for testing these oils are listed in the Reference Section of this report. Laboratory test conditions which must be followed for fish bioassays are described in the following section. This is followed by a number of explanatory notes, intended to clarify certain aspects of the test conditions.

4.1 Test procedure

4.1.1 Static bioassays shall be conducted to determine if the water soluble fraction of the base oil is lethal to rainbow trout.

4.1.2 The tests are to be conducted in freshwater of suitable quality.

4.1.3 Test containers must be made of non-toxic, non-corrodible materials such as glass, porcelain, fibreglass, stainless steel, polyethylene, acrylic, polypropylene or reinforced polyester.

4.1.4 Rainbow trout (Salmo gairdneri Richardson) are to be used as the test species.

4.1.5 Only healthy stocks of properly acclimated (as described in Section 5) fish are to be used and individual fish may only be used once.

4.1.6 Individual fish are to have been actively feeding for a minimum of two weeks, and are to weigh between 0.5 and 5.0 grams. The length of the largest fish must not be more than two times that of the smallest fish in the same test.

4.1.7 A minimum of ten test fish are to be exposed to the test solution. A control test in which at least ten fish are exposed to the control water for the same time period must be conducted concurrently. In order to meet loading density requirements, it is permissable to run duplicate or triplicate tests and to pool the results together.

4.1.8 The test is rendered invalid if fish mortality in the control water exceeds 10 percent.

4.1.9 For every one gram of fish, there must be at least 2.0 litres of test solution or control water for every 24 hours of exposure.

4.1.10 The minimum water depth in any test vessel must be 15 cm.

4.1.11 The test must be conducted at $15 \pm 1°C$.

4.1.12 Prior to and during the test, the test solution shall not be aerated.

4.1.13 The pH of the test solutions shall not be adjusted.

4.1.14 No food or chemicals are to be added to the test solutions prior to or during the tests.

4.1.15 The total number of dead fish must be recorded daily throughout the test period of each test solution. Dead fish must be removed at least once each day. Fish are considered dead when they fail to respond to gentle prodding and show no opercular movement.

4.1.16 A WSF of mineral oil shall be considered acutely lethal to rainbow trout if 50 percent or more of the WSF exposed fish die within 96 hours.

4.1.17 Oils for bioassay tests should be stored and transported in non-toxic containers sealed to exclude air. Storage in the dark and refrigeration at 4°C are desirable. Samples r acute toxicity tests should not be frozen during storage or transportation.

5. EXPLANATORY NOTES

5.1 Holding and Acclimation of Fish

Fish should be acclimated to the following laboratory conditions over a period of at least two weeks prior to testing. The purpose of acclimation is to determine that fish are healthy and to allow them to adjust to the holding conditions. A record should be kept of water quality, fish disease and mortality during acclimation and holding.

5.1.1 Water Quality. Holding, dilution and control water can be natural freshwater or dechlorinated municipal water. The same water should be used for all three purposes. It is recommended that water quality be monitored according to the parameters and frequency in Table 1.

5.1.2 Holding Facilities. The acclimation tanks and accessories must be made of non-toxic, non-corrodible materials, such as glass, porcelain, fibreglass, stainless steel, polyethylene, acrylic, polypropylene or reinforced polyester.

Copper, galvanized material, natural rubber, brass and lead must not come in contact with holding water, dilution water or test solutions. The acclimation tanks should be located away from any physical disturbances and preferably in a location separate from the test vessels. During acclimation, a constant flow of water through the holding tanks is necessary. Rates of water exchange should be a minimum of 1.4 L/g of fish per day. To prevent overcrowding there should be at least one litre of water for every 10 g of fish in the holding tank.

If recirculation of holding tank water is required, a suitable filtration system must be utilized to ensure good water quality in the holding tanks. If recirculated water is used for holding the test fish, that same water should be used for dilution water in the bioassays. Prior to any tests being started, ammonia, nitrate and nitrite should be determined on the recirculated water.

TABLE 1 RECOMMENDED PARAMETERS AND SAMPLING FREQUENCY FOR DILUENT AND CONTROL WATERS

Parameter	Frequency	
	Monthly	Twice Yearly (Spring and Fall)
Total ammonia nitrogen	X	
Specific conductance	X	
Dissolved oxygen	X	
Nonfilterable residue	X	
pH	X	
Temperature	X	
Total organic carbon	X	
Total: aluminum, arsenic, calcium, cadmium, cobalt, chromium, copper, iron, mercury, potassium, magnesium, manganese, sodium, nickel, lead and zinc		X
Residual Chlorine (if municipal water is used)	4X	

5.1.3 Photoperiod. The photoperiod for acclimation and testing should be a constant sequence of 14 hours of light and 10 hours of darkness. It is recommended that lights be turned on or off gradually over at least 15 minutes.

Light intensity at the surface of the holding tanks should be 20 to 30 lux.

5.1.4 Aeration in Holding Tanks. Supplementary aeration by filtered, oil-free compressed air should be provided if necessary to keep the dissolved oxygen level at greater than 80 percent saturation.

5.1.5 Cleaning of Holding Tanks. Holding tanks should be clean. Designs for tanks which are partially self-cleaning are available. However, periodic siphoning of settled material is usually necessary. Tanks should also be disinfected between batches of fish to minimize the occurrence and transmittal of disease.

5.1.6 Temperature. Since the temperature of the holding water used during the transfer of fish from the hatchery to the laboratory may be outside of the acceptable limits for the test (15 ± 2°C), it may be necessary to gradually change the temperature until the desired acclimation temperature is reached. The temperature of the holding tank water should not be changed at a rate greater than 2.0°C per day. Once the holding tank water has reached 15°C, the fish should be held at this temperature for a 14-day acclimation period prior to testing.

5.1.7 Feeding. Rainbow trout fingerling should be fed a recognized commercially prepared fish food. Fish should be fed daily in the holding tanks but they are not to be fed for 24 hours prior to the start of or during the bioassay tests.

5.1.8 Disease Detection and Control. Hatchery raised, certified disease-free rainbow trout are available from commercial hatcheries. Daily inspection of fish in holding tanks is an essential part of the detection of disease and "healthy" versus "unhealthy" conditions should be recognized. Fish exhibiting signs of disease and/or parasites are unsuitable for use in aquatic toxicity tests.

5.2 Test and Control Vessels

Test vessels must be constructed of the non-toxic materials described in section 5.1.2. However, it is strongly suggested that disposable polyethylene liners be placed in each tank because oil residues are difficult to clean from the sides of test containers.

Test vessels, liners and other equipments used for the preparation of test solutions should be cleaned thoroughly and rinsed with dilution water in accordance with good laboratory practice.

5.3 Starting the Bioassays

Each bioassay shall consist of one test on the 100 percent WSF solution and a control test. Since several containers will usually be used to prepare the WSF, the individual WSF solutions should be pooled together to provide a homogenous sample.

In order to meet the criteria of 2 L/g·d and 10 fish exposed to both the WSF and the control, it may be necessary to conduct the tests in duplicate tanks with five fish in each.

Temperature, dissolved oxygen levels and pH shall be recorded for each test vessel and the fish should be distributed to the test containers in a random fashion. To achieve this, some system of randomization of test vessels (random tables, dice, numbered cards) should be utilized.

5.4 Daily Observations

Temperature, dissolved oxygen and pH must be measured and recorded daily. Observations of mortality must also be made daily and dead fish must be removed and measured for weight and length.

5.5 Bioassay Record Sheets

The information shown in Table 2 should be recorded on bioassay record sheets.

TABLE 2 INFORMATION TO BE RECOVERED ON BIOASSAY INFORMATION RECORD SHEETS

A. Laboratory Details

- Laboratory identification
- Personnel conducting tests

B. Sample Details

- Sample source
- Sample description
- Collection date and time
- Storage/shipping details
- Date and time received in laboratory

C. Control/Diluent Water Details

- Water type
- Water source (date, time collected if not tap water)
- Current values for parameters listed in Table 1

D. Test Organism Details

- Species
- Location and date of acquisition
- Treatments
- Acclimation details
- Food type and quantity fed
- Feeding schedule
- Average length, weight, with ranges
- Holding temperature
- Photoperiod

E. Test Details

- Test type performed
- Exposure duration
- Exposure dates
- Photoperiod
- Test temperature
- Test depth
- Test volume, test vessel description
- Number of test organisms per test vessel
- Loading rate/day
- Concentrations established

F. Test Observation Details

- Effects, mortalities/test concentration/observation time
- pH, D.O., temperature/test concentration/observation time

G. Test Result Details

- Number of mortalities in WSF and control
- A pass or fail statement (see 4.1.16)

H. Other Appropriate Details

6. ACKNOWLEDGEMENTS

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APPENDIX 3

IV/GRAV/RETORT ANALYSIS OF OIL

The following analytical procedures for measuring oil and grease are attached:

1. Babcock Flask Method (EPS Atlantic Lab Manual)
2. Soxhlet Extraction-Gravimetric (EPS Lab Manual).

APHA 503A	Partition - Gravimetric Method
APHA 503B	Partition - Infrared Method (Tentative)
APHA 503C	Soxhlet Extraction Method
APHA 503D	Extraction Method for Sludge Samples
APHA 503E	Hydrocarbons

1. Babcock Flask Method (EPS Atlantic Lab Manual)

OIL AND GREASE

BABCOCK FLASK METHOD

1. **Principle.** Currently, grease in wastewaters is assessed by the manner it affects receiving bodies of water, treatment plant operation, and land surfaces rather than by its chemical composition. Grease may be said to include fats, oils, and waxes. Lipids have been defined as insoluble in water but soluble in one or more organic solvents, such as ether, chloroform, benzene and acetone. They are actual or potential esters of fatty acids and are utilizable by living organisms. Because the term grease can be defined in a similar manner, the term lipid can be used synonymously with the term grease. In this method, a sample is placed in a Babcock flask and concentrated sulphuric acid is added. After the flask has been in a water bath for a time, it is centrifuged and reheated in the water bath. The percentage of oil is read directly from the calibrated portion on the neck of the flask.

2. **Scope and Application.** This method can be applied to natural waters and wastewaters with an oil content in the range of 0.01% to 0.5 % oil (appropriate dilution to bring within the range may be required).

3. **Interferences.** There are no significant interferences.

4. **Reagents.** Sulphuric acid: Reagent grade.

5. **Procedure.** Pipette 17.6 mL sample into a Babcock flask. Cool a little and add 25 mL concentrated sulphuric acid. **CAUTION!** Place flask in 80 to 90°C water bath for three minutes. Do not jar or bump flask as explosion may occur. Centrifuge at 1000 rpm for three minutes. Reheat in water bath for two minutes. Add water to the flask to raise the oil within the calibrated portion of the neck. Recentrifuge and read the percentage of oil directly from the neck of the flask.

6. **Calculations.** The concentration of oil may be determined by direct reading of the calibrated portion of the neck of the flask.

7. **Storage and Preservation.** In a clean glass bottle, place 100 mL of sample and acidify with 0.5 mL H_2SO_4. Keep the sample cold.

8. **Precision and Accuracy.** In a single laboratory (Environmental Protection, Atlantic Region), the precision of a mean sample value of 0.272 % was 12.5 %. The accuracy of a 0.02 % standard was 0.5 %.

2. Soxhlet Extraction - Gravimetric (EPS Lab Manual).

OILS AND GREASE

SOXHLET EXTRACTION – GRAVIMETRIC

1. **Scope and Application.** This method is used to quantitatively determine groups of substances with similar physical characteristics on the basis of their common solubility in a particular solvent. The term "oils and grease" therefore includes such things as hydrocarbons, fatty acids, soaps, fats, waxes, oils and any other material which can be extracted by the solvent from an acidified sample and that is not volatilized during the solvent removal. It can therefore be said that "oils and grease" are defined by the method used for their extraction (i.e., n-hexane extractable compounds or freon extractable compounds, etc.).

The method is generally suited for biological lipids and mineral hydrocarbons in natural waters or domestic wastewaters. Industrial wastes, however, may yield low results because of the presence of natural greases or synthetic compounds that are not recovered by the standard procedure. The concentration range is from 5 mg/L.

2. **Sample Condition.** A sample of 800 mL and a duplicate should be collected in glass bottles. The bottle should not be filled to the top. Two mL of sulphuric acid should be added as a preservative.

3. **Method Principle.** Compounds which are soluble in the solvent are extracted in a Soxhlet extraction apparatus thereby taking advantage of the partition coefficients of the compounds in question. Under acid conditions, any fatty acids present are converted to their acid form and are also extracted. The method itself is a catch-all method. It is "technician dependent" to a certain extent and has many interferences.

4. **Interferences.**
   1. The method is extremely empirical and duplicate results can be obtained only by strict adherence to all details (1).
   2. By definition, any substance soluble in the solvent of choice will be called "oils and grease". This could include organic dyes, other organic compounds and sulphur.
   3. It must also be noted that different greases will have different solubilities in the solvent, therefore, time of extraction plays a very important part in the determination of a particular constituent.
   4. Any volatile substances which volatilize at or below 103°C will be lost.
   5. An increase in weight will occur for compounds which oxidize in the drying process.

5. **Precision and Accuracy.** Standard Methods (1) quotes a recovery of 88 % with a standard deviation of ±1.1 mg for No. 2 fuel oil, using this Soxhlet method.

6. **Apparatus.**
   1. Filter apparatus (Whatman No. 40 - 9 cm diameter paper or equivalent).
   2. Soxhlet extraction apparatus.

7. Reagents.

1. Concentrated sulphuric acid, reagent grade.
2. n-Hexane, petroleum ether or freon:
   In the procedure which follows petroleum ether is used.
3. Diatomaceous-silica filter aid suspension:
   Suspended 10 g of Celite-503 in one litre of deionized water.

8. Procedure.

1. Acidify sample with 2 mL of H_2SO_4 per litre (pH 1).
2. Prepare the filter apparatus by placing two circles of 9-cm diameter No. 40 Whatman filter paper in a Buchner funnel. With suction, pass 100 mL of the shaken filter aid suspension through the filter, followed by a one-litre deionized water wash. Apply vacuum until filter cake is reasonably dry. Prepare blank also (Note 1).
3. Mark the bottle at the level of the sample. After the sample has been used, add water up to this mark to measure the sample volume.
4. Filter all the sample through the prepared filter with suction.
5. Fold the filter paper, filter cake and residue so that no material can escape and place it in the Soxhlet thimble.
6. Wipe the inside of the sample bottle, lid, and filter funnel with filter paper soaked in petroleum ether. Place this filter paper in the thimble. Put the thimble in the Soxhlet extraction apparatus.
7. Weigh an appropriate flask (125 mL) that has been dried at 103°C for 1 hour. Add 70 mL of petroleum ether to this flask and assemble the Soxhlet extraction apparatus.
8. The heating element should be set such that the rate of extraction is approximately 20 cycles per hour for a period of 4 hours.
9. Evaporate the petroleum ether carefully from the flask, then heat the flask at 103°C for 10 minutes to remove residual water.
10. Cool the flask in a desiccator and weigh the flask.

9. Notes. The samples and blanks must be treated at the same time and in the same manner for a valid comparison.

10. Calculations.

$$\frac{(A-B) \times 10^6}{V} = \text{mg/L total grease}$$

where:
A = weight of extracted sample (g)
B = weight of extracted blank (g)
V = volumes of sample in (mL)

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503. OIL AND GREASE

In the determination of oil and grease, an absolute quantity of a specific substance is not measured. Rather, groups of substances with similar physical characteristics are determined quantitatively on the basis of their common solubility in trichlorotrifluoroethane. "Oil and grease" is any material recovered as a substance soluble in trichlorotrifluoroethane. It includes other material extracted by the solvent from an acidified sample (such as sulphur compounds, certain organic dyes, and chlorophyll) and not volatilized during the test. It is important that this limitation be understood clearly. Unlike some constituents that represent distinct chemical elements, ions, compounds, or groups of compounds, oils and greases are defined by the method used for their determination.

The methods presented here are suitable for biological lipids and mineral hydrocarbons. They also may be suitable for most industrial wastewaters or treated effluents containing these materials, although sample complexity may result in either low or high results because of lack of analytical specificity. The method is not applicable to measurement of low-boiling fractions that volatilize at temperatures below 70°C.

1. **Significance.** Certain constituents measured by the oil and grease analysis may influence wastewater treatment system. If present in excessive amounts, they may interfere with aerobic and anaerobic biological processes and lead to decreased wastewater treatment efficiency. When discharged in wastewater or treated effluents, they may cause surface films and shoreline deposits leading to environmental degradation.

A knowledge of the quantity of oil and grease present is helpful in proper design and operation of wastewater treatment systems and also may call attention to certain treatment difficulties.

2. **Selection of Method.** For liquid samples, three methods are presented: the partition-gravimetric method (A); the partition-infrared method (B); and the Soxhlet method (C). Method B is designed for samples that might contain volatile hydrocarbons that otherwise would be lost in the solvent removal operations of the gravimetric procedure. Method C is the method of choice when relatively polar, heavy petroleum fractions are present, or when the levels of nonvolatile greases may challenge the solubility limit of the solvent. For low levels of oil and grease (<10 mg/L), Method B is the method of choice because gravimetric methods do not provide the needed precision.

Method D is a modification of the Soxhlet Method and is suitable for sludges and similar materials. Method E can be used in conjunction with Methods A, B, C, or D to obtain a hydrocarbon measurement in addition to, or instead of, the oil and grease measurement. This method separates hydrocarbons from the total oil and grease on the basis of polarity.

3. **Sampling and Storage.** Collect a representative sample in a wide-mouth glass bottle that has been rinsed with the solvent to remove any detergent film, and acidify in the sample bottle. Collect a separate sample for an oil and grease determination and do not subdivide in the laboratory. When information is required about average grease concentration over an extended period, examine individual portions collected at prescribed time intervals to eliminate losses of grease on sampling equipment during collection of a composite sample.

In sampling sludges, take every possible precaution to obtain a representative sample. When analysis cannot be made immediately, preserve samples with 1 mL conc. HCl/80 g sample. Never preserve samples with $CHCl_3$ or sodium benzoate.

503 A. PARTITION-GRAVIMETRIC METHOD

General Discussion:

Principle: Dissolved or emulsified oil and grease is extracted from water by intimate contact with trichlorotrifluoroethane. Some extractables, especially unsaturated fats and fatty acids, oxidize readily; therefore, special precautions regarding temperature and solvent vapour displacement are included to minimize this effect.

Interference: Trichlorotrifluoroethane has the ability to dissolve not only oil and grease but also other organic substances. No known solvent will selectively dissolve only oil and grease. Solvent removal results in the loss of short-chain hydrocarbons and simple aromatics by volatilization. Significant portions of petroleum distillates from gasoline through No. 2 fuel oil are lost in this process. In addition, heavier residuals of petroleum may contain a significant portion of materials that are not extractable with the solvent.

Apparatus:

- **Separatory funnel,** 1 L, with TFE* stopcock.
- **Distilling flask,** 125 mL.
- **Water bath.**
- **Filter paper,**** 11 cm diameter.

Reagents:

- **Hydrochloric acid,** HCl, 1 + 1.
- **Trichlorotrifluoroethane***** (1,1,2-trichloro-1,2,2-trifluoroethane), boiling point 47°C. The solvent should leave no measurable residue on evaporation; distill if necessary. Do not use any plastic tubing to transfer solvent between containers.
- **Sodium sulphate,** Na_2SO_4, anhydrous crystal.

Procedure:

Collect about 1 L of sample and mark sample level in bottle for later determination of sample volume. Acidify to pH 2 or lower; generally, 5 mL HCl is sufficient. Transfer to a separatory funnel. Carefully rinse sample bottle with 30 mL trichlorotrifluoroethane and add solvent washings to separatory funnel. Preferably shake vigorously for 2 minutes. However, if it is suspected that a stable emulsion will form, shake gently for 5 to 10 minutes. Let layers separate. Drain solvent layer through a funnel containing solvent-moistened filter paper into a clean, tared distilling flask. If a clear solvent layer cannot be obtained, add 1 g Na_2SO_4 to the filter paper cone and slowly drain emulsified solvent onto the crystals. Add more Na_2SO_4 if necessary. Extract twice more with 30 mL solvent each but first rinse sample container with each solvent portion. Combine extracts in tared distilling flask and wash filter paper with an additional 10 to 20 mL solvent. Distill solvent from distilling flask in a water bath at 70°C. Place flask on a water bath at 70°C for 15 minutes and draw air through it with an applied vacuum for the final 1 minute. Cool in a desiccator for 30 minutes and weigh.

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* Teflon or equivalent.
** Whatman No. 40 or equivalent.
*** Freon or equivalent.

Calculation:

If the organic solvent is free of residue, the gain in weight of the tared distilling flask is mainly due to oil and grease. Total gain in weight (A) of tared flask less calculated residue (B) from solvent blank is the amount of oil and grease in the sample:

$$\text{mg oil and grease/L} = \frac{(A - B) \times 1000}{\text{mL sample}}$$

Precision and Accuracy

Methods A, B, and C were tested by a single laboratory on a sewage sample. By this method the oil and grease concentration was 12.6 mg/L. When 1-L portions of the sewage were dosed with 14.0 mg of a mixture of No. 2 fuel oil and Wesson oil, recovery of added oils was 93 % with a standard deviation of 0.9 mg.

503 B. PARTITION-INFRARED METHOD (TENTATIVE)

General Discussion:

Principle: Although the extraction procedure for this method is identical to that of Method A, infrared detection permits the measurement of many relatively volatile hydrocarbons. Thus, the lighter petroleum distillates, with the exception of gasoline, may be measured accurately. Adequate instrumentation allows for the measurement of as little as 0.2 mg oil and grease/L.

Interference: Some degree of selectivity is offered by this method to overcome some of the coextracted interferences discussed in Method A. Heavier residuals of petroleum may contain a significant portion of materials insoluble in trichlorotrifluoroethane.

Definitions: A "known oil" is defined as a sample of oil and/or grease that represents the only material of that type used or manufactured in the processes represented by a wastewater. An "unknown oil" is defined as one for which a representative sample of the oil or grease is not available for preparation of a standard.

Apparatus:

- **Separatory funnel,** 1 L, with TFE* stopcock.
- **Infrared spectrophotometer,** double beam, recording.
- **Cells,** near-infrared silica.
- **Filter paper,**** 11 cm diameter.

Reagents:

- **Hydrochloric acid,** HCl, 1 + 1.
- **Trichlorotrifluoroethane,** See 503A.3b.
- **Sodium sulphate,** Na_2SO_4, anhydrous, crystal.
- **Reference oil:** Prepare a mixture, by volume, of 37.5 % iso-octane, 37.5 % hexadecane, and 25 % benzene. Store in sealed container to prevent evaporation.

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* Teflon or equivalent.

** Whatman No. 40 or equivalent.

Procedure:

Refer to Method A for sample collection, acidification, and extraction. Collect combined extracts in 100-mL volumetric flask and adjust final volume to 100 mL with solvent.

Prepare a stock solution of known oil by rapidly transferring about 1 mL (0.5 to 1.0 g) of the oil or grease to a tared 100-mL volumetric flask. Stopper flask and weigh to nearest milligram. Add solvent to dissolve and dilute to mark. If the oil identity is unknown (¶ 1c) use the reference oil (¶ 3d) as the standard. Using volumetric techniques, prepare a series of standards over the range of interest. Select a pair of matched near-infrared silica cells. A 1-cm-path-length cell is appropriate for a working range of about 4 to 40 mg. Scan standards and samples from 3200 to 2700 cm^{-1} with solvent in the reference beam and record results on absorbance paper. Measure absorbances of samples and standards by constructing a straight baseline over the scan range and measuring absorbance of the peak maximum at 2930 cm^{-1} and subtracting baseline absorbance at that point. If the absorbance exceeds 0.8 for a sample, select a shorter pathlength or dilute as required. Use scans of standards to prepare a calibration curve.

Calculation:

$$\text{mg oil and grease/L} = \frac{A \times 1000}{\text{mL sample}}$$

where: A = mg of oil or grease in extract as determined from calibration curve.

Precision and Accuracy:

See 503.A. By this method the oil and grease concentration was 17.5 mg/L. When 1-L portions of the sewage were dosed with 14.0 mg of a mixture of No. 2 fuel oil and Wesson oil, the recovery of added oils was 99 % with a standard deviation of 1.4 mg.

503 C. SOXHLET EXTRACTION METHOD

General Discussion:

Principle: Soluble metallic soaps are hydrolyzed by acidification. Any oils and solid or viscous greases present are separated from the liquid samples by filtration. After extraction in a Soxhlet apparatus with trichlorotrifluoroethane, the residue remaining after solvent evaporation is weighed to determine the oil and grease content. Compounds volatilized at or below 103°C will be lost when the filter is dried.

Interference: The method is entirely empirical and duplicate results can be obtained only by strict adherence to all details. By definition, any material recovered is oil and grease and any filtrable trichlorotrifluoroethane-soluble substances, such as elemental sulphur and certain organic dyes, will be extracted as oil and grease. The rate and time of extraction in the Soxhlet apparatus must be exactly as directed because of varying solubilities of different greases. In addition, the length of time required for drying and cooling extracted material cannot be varied. There may be a gradual increase in weight, presumably due to the absorption of oxygen, and/or a gradual loss of weight due to volatilization.

Apparatus:

- **Extraction apparatus.** Soxhlet.
- **Vacuum pump** or other source of vacuum.
- **Buchner funnel,** 12 cm.
- **Electric heating mantle.**
- **Extraction thimble,** paper.
- **Filter paper,*** 11 cm diameter.
- **Muslin cloth disks,** 11 cm diameter.

Reagents:

- **Hydrochloric acid,** HCl, 1 + 1.
- **Trichlorotrifluoroethane:** See 503A.3b.
- **Diatomaceous-silica filter aid suspension,** 10 g/L distilled water.

Procedure:

Collect about 1 L of sample in a wide-mouth glass bottle and mark sample level in bottle for later determination of sample volume. Acidify to pH 2 or lower; generally, 5 mL HCl is sufficient. Prepare a filter consisting of a muslin cloth disk overlaid with filter paper. Wet paper and muslin and press down edges of paper. Using a vacuum, pass 100 mL filter aid suspension through prepared filter and wash with 1 L distilled water. Apply vacuum until no more water passes filter. Filter acidified sample. Apply vacuum until no more water passes through filter. Using forceps, transfer filter paper to a watch glass. Add material adhering to edges of muslin cloth disk. Wipe sides and bottom of collecting vessel and Buchner funnel with pieces of filter paper soaked in solvent, taking care to remove all films caused by grease and to collect all solid material. Add pieces of filter paper to filter paper on watch glass. Roll all filter paper containing sample and fit into a paper extraction thimble. Add any pieces of material remaining on watch glass. Wipe watch glass with a filter paper soaked in solvent and place in paper extraction thimble. Dry filled thimble in a hot-air oven at 103°C for 30 minutes. Fill thimble with glass wool or small glass beads. Weigh extraction flask. Extract oil and grease in a Soxhlet apparatus, using trichlorotrifluoroethane at a rate of 20 cycles/h for 4 hours. Time from first cycle. Distill solvent from extraction flask in a water bath at 70°C for 15 minutes and draw air through it using an applied vacuum for the final 1 minute. Cool in a desiccator for 30 minutes and weigh.

Calculation:

See section 503A.5.

Precision and Accuracy:

See Section 503A.6. By this method the oil and grease concentration was 14.8 mg/L. When 1-L portions of the sewage were dosed with 14.0 mg of a mixture of No. 2 fuel oil and Wesson oil, the recovery of added oils was 88 % with a standard deviation of 1.1 mg.

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* Whatman No. 40 or equivalent.

503 D. EXTRACTION METHOD FOR SLUDGE SAMPLES

General Discussion:

Principle: Drying acidified sludge by heating leads to low results. Magnesium sulphate monohydrate is capable of combining with 75 % of its own weight in water in forming $MgSO_4 \cdot 7H_2O$ and is used to dry sludge. After drying, the oil and grease can be extracted with trichlorotrifluoroethane.

Interference: See 503C.1b.

Apparatus:

- **Extraction apparatus,** Soxhlet.
- **Vacuum pump** or other source of vacuum.
- **Extraction thimble,** paper.
- **Grease-free cotton:** Extract oil and grease from non-absorbent cotton using solvent.

Reagents:

- **Hydrochloric acid,** HCl, conc.
- **Magnesium sulphate monohydrate:** Prepare $MgSO_4$ by overnight drying of a thin layer in an oven at 150°C.
- **Trichlorotrifluoroethane:** See 503A.

Procedure:

In a 150-mL beaker weigh a sample of wet sludge, 20 ± 0.5 g, of which the dry-solids content is known. Acidify to pH 2.0 (generally, 0.3 mL conc. HCl is sufficient). Add 25 g $MgSO_4 \cdot H_2O$. Stir to a smooth paste and spread on sides of beaker to facilitate subsequent removal. Set stand until solidified, 15 to 30 minutes. Remove solids and grind in a porcelain mortar. Add the powder to a paper extraction thimble. Wipe beaker and mortar with small pieces of filter paper moistened with solvent and add to thimble. Fill thimble with glass wool or small glass beads. Extract in a Soxhlet apparatus, using trichlorotrifluoroethane, at a rate of 20 cycles/h for 4 hours. If any turbidity or suspended matter is present in the extraction flask, remove by filtering through grease-free cotton into another weighed flask. Rinse flask and cotton with solvent. Distill solvent from extraction flask in water at 70°C. Place flask on a water bath at 70°C for 15 minutes and draw air through it using an applied vacuum for the final 1 minute. Cool in a desiccator for 30 minutes and weigh.

Calculation:

$$\text{Oil and grease as \% of dry solids} = \frac{\text{gain in weight of flask, g} \times 100}{\text{weight of wet solids, g} \times \text{dry solids fraction}}$$

Precision:

The examination of six replicate samples of sludge yielded a standard deviation of 4.6 %.

503 E. HYDROCARBONS

Significance:

In the absence of specially modified industrial products, oil and grease is composed primarily of fatty matter from animal and vegetable sources and hydrocarbons of petroleum origin. A knowledge of the percentage of each of these constituents in the total oil and grease minimizes the difficulty in determining the major source of the material and simplifies the correction of oil and grease problems in wastewater treatment plant operation and stream pollution abatement.

General Discussion:

Principle: Silica gel has the ability to absorb polar materials. If a solution of hydrocarbons and fatty materials in trichlorotrifluoroethane is mixed with silica gel, the fatty acids are selectively removed from solution. The materials not eliminated by silica gel adsorption are designated hydrocarbons by this test.

Interference: The more polar hydrocarbons, such as complex aromatic compounds and hydrocarbon derivatives of chlorine, sulphur, and nitrogen, may be adsorbed by the silica gel. Any compounds other than hydrocarbons and fatty matter recovered by the procedures for the determination of oil and grease also interfere.

Reagents:

- **Trichlorotrifluoroethane:** See 503A.
- **Silica gel,** 60 to 200 mesh.* Dry at 110°C for 24 hours and store in a tightly sealed container.

Procedure:

Use the oil and grease extracted by Method A, B, C, or D for this test. When only hydrocarbons are of interest, introduce this procedure in any of the previous methods before final measurement. When hydrocarbons are to be determined after total oil and grease has been measured, redissolve, if necessary, the extracted oil and grease in trichlorotrifluoroethane. To 100 mL solvent containing less than 100 mg fatty material, add 3.0 g silica gel. Stopper container and stir on a magnetic stirrer for 5 minutes. For infrared measurement of hydrocarbons no further treatment is required before measurement as described in Method B. For gravimetric determinations, filter solution through filter paper and wash silica gel and filter paper with 10 mL solvent and combine with filtrate before performing the solvent stripping steps outlined in Methods A, C, or D.

Calculation:

Calculate hydrocarbon concentration (mg/L) as in oil and grease (Method A, B, C, or D).

Precision and Accuracy:

The accuracy of this determination cannot be measured directly in wastewaters. The following data, obtained on synthetic samples, are indicative for natural animal, vegetable, and mineral products, but cannot be applied to the specialized industrial products previously discussed.

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* Davidson Grade 950 or equivalent.

For hydrocarbon determinations on 10 synthetic solvent extracts containing known amounts of a wide variety of petroleum products, average recovery was 97.2 %. Similar synthetic extracts of Wesson oil, olive oil, Crisco, and butter gave 0.0 % recovery as hydrocarbons measured by infrared analysis.

RETORT ANALYSIS

Analysis method:

1. The empty mud chamber was weighed.
2. The chamber was filled with the cuttings sample and reweighed.
3. The chamber was placed in the retort and the cuttings heated until the pilot light went out (>45 minutes).
4. The mud chamber and distillate receiver were removed and allowed to cool to ambient temperature.
5. The volume of oil and the volume of water retorted were measured.
6. The mud chamber was reweighed.

Calculations:

1. Weight of water = volume of water x 1.0.
2. Weight of oil = volume of oil x 0.84.
3. Oil content (%, wet weight) $= \frac{\text{weight of oil x 100}}{\text{weight of wet cuttings}}$
4. Oil content (g oil/100 g cuttings, dry weight)

$$= \frac{\text{weight of oil x 100}}{\text{weight of retorted cuttings}}$$

APPENDIX 4

COGLA GUIDELINES FOR THE USE OF OIL-BASED DRILLING MUDS

GUIDELINES FOR THE USE OF OIL-BASED DRILLING MUDS

November 1985

CANADA OIL AND GAS LANDS ADMINISTRATION
GUIDELINES
FOR THE USE OF OIL-BASED DRILLING MUDS

1. SCOPE AND OBJECTIVES

1.1 These guidelines apply to the use of oil-based muds in exploration and production drilling on all offshore Canada Lands. Their general objective is to ensure that these drilling fluids can be used in a safe and environmentally acceptable manner.

1.2 Because the use of oil-based drilling muds is under development in Canada, the operator is encouraged to propose and discuss with COGLA new procedures and evolving technologies which may in the future lead to general or special modifications of these guidelines. The guidelines will be reviewed on at least an annual basis.

1.3 Use of oil-based drilling muds is not considered routine in northern waters at this time. The operator should also be aware that special conditions modifying these guidelines may apply in circumstances of environmental sensitivity or concern (e.g., shallow water less than 20 m, critical biological habitat, etc.). Where such circumstances can be anticipated, the operator is encouraged to submit proposals for the use of oil-based muds as early as possible to allow for full consultation.

1.4 In all instances, the drilling activities must be in compliance with applicable requirements of the Canada Oil and Gas Drilling Regulations and the Canada Oil and Gas Production and Conservation Regulations.

2. BASE OIL

2.1 The base oil should be of low toxicity and of low aromatic hydrocarbon content, especially by comparison to diesel oil. (By way of general guidance, it is noted that low-toxicity base oils of less than 5 percent aromatic content have been used effectively by the Canadian drilling industry. Base oils of higher aromatic content may be considered as special cases if the industry is able to demonstrate acceptably low toxicity in both acute and chronic exposure regimes.)

2.2 The content of polycyclic aromatics in particular is encouraged to be as low as can be achieved through best practicable technology. Higher molecular weight polycyclic aromatic hydrocarbons (4-7 ring aromatics), in particular, should not be present in the base oil.

2.3 Oil-based drilling muds may contain diesel or similar highly polynuclear aromatic oils as the continuous phase only if the mud and cuttings treatment and disposal system is self-contained. Such cuttings require special handling and should not be disposed of into the sea. (Land disposal or burning constitute special cases and may require special permits from the appropriate jurisdictions.)

2.4 The base oil should be non-acutely toxic in a standard toxicity test. The recommended standard bioassay is a static test using rainbow trout fingerlings, in which exposure is for 96 hours to 100 percent water soluble fraction of the base oil. Details on this screening test protocol can be obtained through COGLA or the Environmental Protection Service of Environment Canada. In the event that the base oil has already been screened for toxicity under a different protocol, the operator should substantiate that the existing test data allow comparative evaluation of the proposed base oil.

2.5 The other components of the anticipated drilling mud formulation are screened routinely by COGLA on the basis of available toxicity data. In all cases, individual

components should be chosen on the basis of best practicable technology, to satisfy technical requirements and achieve the lowest toxicity possible.

3. APPLICATION FOR USE AND INFORMATION REPORTING REQUIREMENTS

3.1 The operator intending to use oil-based drilling mud should clearly state this intention in the supporting documentation supplied to the oil and gas regulator when seeking approvals for exploration and production drilling programs. The reasons for the use of oil-based mud systems should be identified.

3.2 Application may be considered at the well drilling approval stage when the proposed use of oil-based mud is in presence to operating conditions which were unforeseen at the drilling program approvals state.

3.3 The following information should be supplied in the operator's application:

a) list of mud components by chemical or trade name;
b) the proportions of mud ingredients expressed in SI units;
c) the properties of the base oil (pour point, flash point, aniline point, specific gravity, kinematic viscosity), determined according to ASTM standard tests;
d) percent total aromatics, quantitative fractional composition of all hydrocarbons in the base oil determined according to ASTM standard tests;
e) information on acute toxicity for the mud components with respect to aquatic organisms and humans, where such data are drawn from existing data sources (Toxicity data may be requested for new products or compounds for which there is no information available);
f) the approximate total mass or volume of oil-based mud to be used;
g) the depth interval through which the oil-based mud will be used;
h) description of the mud treatment and discharge system to be used on the drilling unit; and
i) description of any additional structural and procedural adaptations on the drilling unit which will allow the safe use of oil-based drilling muds.

3.4 Weekly reports should be provided to the appropriate office of the oil and gas regulator, presenting oil-on-cuttings discharge data, as well as any accidental losses of oil-based mud.

4. ENVIRONMENTAL MONITORING

4.1 Special circumstances in exploration drilling may require that a field (environmental fate and/or effects) monitoring program be conducted with the use of oil-based mud. The requirement for such a program, its design and its implementation will be determined through consultation between the operator and oil and gas regulators.

4.2 A field monitoring program is likely to be required in production drilling using oil-based muds for multiple wells at a single location.

5. DISCHARGES AND COMPLIANCE MONITORING

5.1 No whole mud or base oil shall be discharged in bulk amounts during or after drilling (emergency conditions affecting the safety of the drilling operation are an exception).

5.2 When drilling with oil-based muds, solids control equipment should be operated with a cuttings discharge target of 20 g oil per 100 g dry cuttings, calculated for the period(s) during which oil-based muds were used. Maximum oil retention should not exceed 30 g oil per 100 g dry cuttings, calculated as a daily average or per 100 m drilled.

The regulator will re-evaluate these guidelines, in consultation with operating companies, following further experience in the use and measurement of oil-based drilling muds. The ultimate objective will be the achievement of 15 g oil per 100 g dry cuttings, or some other environmentally acceptable level, consistent with drilling systems in use and characteristics of the formations being drilled.

5.3 A representative sample of cuttings from the solids control system waste stream should be analyzed for oil content by the retort method using standard procedures, and in accordance with an approved schedule. For example, cuttings samples could be taken for each 100 m drilled with oil-based mud, or alternatively, the sampling scheme could be based on geological characteristics. The results of individual samples, daily and weekly averages should be reported once per week to the appropriate office of the oil and gas regulator.

6. OCCUPATIONAL HEALTH AND SAFETY

6.1 The drilling crew should receive appropriate training in the use of the oil-based drilling mud, including training on changes in kick detection techniques, and in its related health and environmental hazards.

6.2 Oil misting should be minimized, and safe levels assured by proper ventilation of the shaker and pit areas and by using submerged agitators and discharges. A recommended standard for allowable air concentrations of hydrocarbon mist is that of the U.S. National Institute of Occupational Safety and Health (NIOSH).

6.3 Drilling unit personnel should be issued protective gear as appropriate to minimize exposure to oil-based mud through contact and inhalation.

6.4 Appropriately designed work areas and clean operating practices should be in place.

7. REPORTING REQUIREMENTS AFTER OPERATIONS

7.1 Included in the final well report submitted to the oil and gas regulator (see, for instance: Drilling for Oil and Gas on Canada Lands, Guidelines and Procedures, Appendix J) the operator should present a summary of the quantity of oil-based mud consumed during drilling. A calculation of the total amount of mud-derived oil which was discharged with cuttings should be presented. The effectiveness of cuttings treatment should be described, giving a summary for weekly means with respect to oil-retention on cuttings, types and sizes of cuttings, and number of samples. Any other losses of base oil or oil-based mud should be reported. The results of any monitoring program should be summarized.

8. FURTHER INFORMATION

Further information may be obtained by contacting COGLA's Environmental Protection Branch, Ottawa. Phone (613) 993-3760.